Institute of Paper Science and Technology

July 2000

Summary of Dues-Funded Research Consortium Projects

FY 00-01

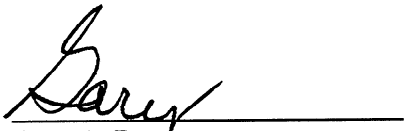
Preface

This book represents the IPST Dues-Funded Research Consortium (DFRC) Project Portfolio for Fiscal Year 2000-2001. The contents of this book can also be found on the IPST Member Channel (http://members.ipst.edu/reports_publications/index.htm). The projects are arranged by Project Advisory Committees (PACs).

Project selection followed the procedures developed by RAC, except that we also used a Portfolio Management approach. In Portfolio Management we rated each proposed project in terms of Value to IPST Membership, Value of using IPST for the work, and the Economic Benefits to a mill implementing the technology. The latter relied strongly on the IPST Economic Model developed by Jaakko Pöyry, with input from the Principal Investigators and the PACs.

Proposals for new projects, as well as projects that we plan to carry forward from the previous year, were prepared and presented to the PACs and the IPST Portfolio Management Team for consideration. The total estimated cost for these projects exceeded the anticipated FY01 DFRC budget. All project proposals and the portfolio management ratings were reviewed by the appropriate PACs. In some cases we also had a PAC numerical score from the rating form developed by the RAC's Project Selection and Oversight (PS&O) Subcommittee. The IPST Portfolio Management Team reviewed all existing data and developed a FY01 DFRC Portfolio that was then presented to the PS&O Subcommittee. The PS&O Subcommittee endorsed the recommendations and the portfolio was presented to the RAC and PAC Chairs for discussion and approval at the March 2000 meeting.

The cost of the total IPST DFRC FY01 Project Portfolio is $4.53 million, compared to the anticipated DFRC revenue of $5.19 million. The difference of $662,000 covers the costs of the GIT-IPST seed grant program, exploratory research, and intellectual property costs associated with the DFRC.



Gary A. Baum
Vice President
Research and Academic Affairs

July 2000

Chemical Pulping and Bleaching

Number - Title	PI	Budget, Thousands
F013-Environmentally Compatible Production of Bleached Chemical Pulp	McDonough	150
F015-Chemical Fundamentals of Bleaching	Lucia	95
F017-Closed Mill Operation	Rudie	115
F030-High Strength, High Yield Chemical Pulps	Li	182
F045-Low-Capital Bleach Plants	McDonough	72
F049-Peroxide Delignification	McDonough	90
F050-Engineered Kraft Fibers	Ragauskas	100
Subtotal		**804**

Chemical Recovery

Number - Title	PI	Budget, Thousands
F02801-Black Liquor Gasification	Sinquefield	144
F02803-Catalytic Destruction of Tars from Black Liquor Gasification	Iisa	20
F032-Control of Evaporator Fouling	Schmidl	150
F03302-Control of Non-Process Elements	Pfromm, Schmidl	78
F03303-Methanol Formation/Emission	Zhu	48
F034-Electrolytic Causticization of Kraft	Pfromm	97
F035-ATR Sensor for On-Line Kraft Liquor Analysis	Zhu	48
F03801-Particulate Formation, Deposition and Hardening	Lien	100
F03804-Fume Sulfation Processes In Recovery Boilers	Iisa	85
F03805-Fate of Heavy Metals in Recovery Boilers	Iisa	50
Subtotal		**820**

Corrosion Control

Number - Title	PI	Budget, Thousands
F036-Mechanisms and Prevention of Stress-Assisted Waterside Corrosion in Recovery Boilers	Singh	30
F037-Corrosivity of Black Liquors	Singh	40
F051-Cost of Corrosion and Related Maintenance in the Pulp and Paper Industry	Singh	50
F052-Corrosion Above Cut-Line in Kraft Recovery Boilers and On-Line Fireside-Corrosion Monitoring Sensor	Singh	160
Subtotal		**280**

Forest Biology

Number - Title	PI	Budget, Thousands
F010-Mass Clonal Propagation of Improved Conifers	Pullman	460
F011-Fundamental Biological Mechanisms: Improved Stem Growth Rates & Fiber Properties	Peter	119
F046-Trees with Easily Pulped Lignin through New Genetic Selection Methods	MacKay, Dimmel	71
Subtotal		**650**

Paper Physics

Number - Title	PI	Budget, Thousands
F008-Acoustic Separation	Gerhardstein	106
F020-Fundamentals of Dimensional Stability	Coffin	92
F023-Micromechanics of Fiber Networks	Ostoja	60
F024-Improving the Refining of Chemical Pulps	Waterhouse	76
F025-Fundamentals of Fiber Bonding	Nanko	105
F026-Fundamentals of Accelerated Creep	Habeger, Coffin	108
F031-Non-Contact Laser Ultrasonic Stiffness Measurements	Habeger	100
F044-Liquid/Substrate Interaction	Robbins	86
Subtotal		**733**

Papermaking

Number - Title	PI	Budget, Thousands
F003-Fluid Dynamics of Suspensions	Aidun	100
F005-Fundamentals of Headbox and Forming Hydrodynamics	Aidun	239
F021-Drying Productivity	Ahrens, Patterson	150
F022-Flow through Porous Media	Karrila	104
F039-Overcoming the Fundamental Water Removal Limitations of Conventional Wet Pressing	Patterson	96
F041-Extending High Intensity Water Removal Principles into the Dryer Section	Ahrens	84
F048-Approach Flow Systems	White	115
Subtotal		**888**

Recycle

Number - Title	PI	Budget, Thousands
F00903-Flotation Deinking Fluid Mechanics	Shrauti	100
F042-On-Line Real Time Quantification of Stickies Contaminants	Banerjee	87
F054-Reversal of Fiber Hornification	Banerjee	30
Subtotal		**217**

Wet End Chemistry

Number - Title	PI	Budget, Thousands
F027-Wet End Chemistry Control Advisor	Scott	50
F043-Wet End Chemistry Understanding and Control	Deng	88
Subtotal		**138**
Total		**4.53M**

Chemical Pulping and Bleaching Project Advisory Committee

DUES-FUNDED PROJECT SUMMARY

Project Title:	**Environmentally Compatible Production of Bleached Chemical Pulp**
Project Number:	**F013**
PAC:	**Chemical Pulping and Bleaching**
Project Staff:	
Principal Investigator:	**T. McDonough**
Co-Investigators:	**C. Courchene**
Research Support Staff:	**Shaket, Turner, Woitkovich**
Proposed FY 00-01 Budget:	**$150,000**
Allocated as Matching Funds:	**None**
Time Allocation:	
Principal Investigator:	**9%**
Co-Investigators:	**18%**
Research Support Staff:	**85%**
Supporting Research:	
Students:	**Aric Bacon, Ph.D., Nour-Eddine Djerdjouri, Ph.D., Erik Lystad, M.S.**
External (Where Matching Is Used):	**Project 4120 "Energy Efficient Kraft Pulping for Highly Bleachable, Low Lignin Content Pulp" (U.S. D.O.E. Paper Mill of the Future). Expected FY 00-01 DOE Funding: $50,000**

RESEARCH LINE/ROADMAP: Line #5 – Reduce emissions of the entire pulp and paper manufacturing process to meet Tier 3 Cluster Rule criteria while maintaining global competitiveness; Line #11 – Improve the ratio of product performance to cost for pulp and paper products 25%.

PROJECT OBJECTIVE: For FY 00/01 we propose to focus the project on two objectives:

(1) Using D(EPO)DED and related sequences, gain an understanding of the effects on fiber properties that will allow fundamental fiber properties to be controlled by chemical means within the fiber line to specified degrees. The fiber properties referred to are fiber tensile strength, wet fiber tensile strength, fiber saturation point, specific volume, specific surface, specific bond strength potential, conformability, and fiber curl. The desired degree of control is such that each property can be increased or decreased to within 20% of conventionally obtained levels, as defined by the results of conventional kraft pulping and D(EPO)DED bleaching.

(2) Identify economically viable bleaching conditions that will reduce the total chlorine dioxide consumption in a conventional D(EPO)DED sequence by 20% without loss of fully bleached pulp brightness or strength.

(3) Complete research activity and provide samples to support achievement of the goals of Project F024, which is directed towards improved understanding of refining, including the dependence of refining mechanisms on fiber properties. This project is being conducted primarily within the Fiber and Paper Physics Research Unit.

BENEFIT TO THE INDUSTRY/DELIVERABLES: Successful completion will allow significant bleached pulp quality improvements and bring the industry a step closer to gaining complete control of fiber properties through pulp mill chemical processing. Bleaching conditions will be identified resulting in retention of 95% of inherent fiber strength through bleaching. Information will be obtained on effects of changes in D(EPO)DED bleaching variables on zero-span strength, curl, microfibril angle and microscopic fiber characteristics. In addition, the project will identify routes to a sharp reduction in chlorine dioxide use, which will reduce effluent treatment requirements and facilitate mill water system closure. Also, results will be obtained demonstrating synergistic interaction with Project F024.

PROJECT STATUS: Earlier work led to the following conclusions:

(1) In the bleaching of southern pine kraft pulp, substitution of ozone for half of the chlorine dioxide in the chlorine dioxide delignification stage decreases the efficiency of delignification and increases viscosity loss. The resulting increase in extracted kappa number causes the expected deterioration of the response of the pulp to bleaching with chlorine dioxide following the extraction stage. All of these effects are much less pronounced after oxygen delignification.

(2) Direct application of the QP sequence to a southern hardwood kraft pulp did not result in very efficient delignification and did not compare well with oxygen delignification. This was probably due in part to the difficulty of removing trace metals and their catalysis of peroxide decomposition. On the other hand, prehydrolysis (A*) to remove uronic acids, in addition to reducing the pulp's kappa number by 37%, can be combined with subsequent chelation to efficiently remove transition metals and maximize the delignification in the peroxide stage. The A*QPD sequence gives a final brightness of 84 when only 0.5% H_2O_2 is applied. Brightnesses up to 88 can be reached with larger amounts of peroxide.

(3) Despite earlier demonstrations of the ability of Mn addition to prevent viscosity loss during the hydrogen peroxide delignification of softwood pulps, we have not yet been able to demonstrate a similar effect in the hydrogen peroxide delignification of hardwood pulp nor in the oxygen delignification of hardwood pulp. In both cases, however, there are indications that useful effects may be seen under more forcing delignification conditions.

(4) Losses in strength from pulping and bleaching processes may be more attributable to mechanical degradation than to chemical degradation. The effects of fiber curl on fiber and sheet properties must be taken into account.

(5) The wet to dry zero span tensile strength ratio appears to be a valid indicator of fiber damage and propensity for cutting during refining.

(6) A method is needed for simulating the response of processed fibers to high-intensity mill refining. Preliminary results with one set of available plates in a 12" laboratory disk refiner showed that the refining intensity is low under these conditions.

By the end of the current fiscal year, we expect to have evaluated "Rapid D/Z" delignification as an alternative to a conventional chlorine dioxide delignification

stage. We anticipate completing our assessment of the importance of changes in fiber curl in the bleach plant as a contributor to the observed effects of bleaching on fiber properties. We will also have completed an experimental evaluation of ozone and oxidative extraction on fiber properties, as compared to pulps conventionally bleached with chlorine dioxide and alkali.

At the end of the current fiscal year we propose to increase emphasis on that part of the project that is devoted to obtaining an improved understanding of the effects of delignification processes on fiber properties. We also propose a new effort on improving the efficiency of chlorine dioxide-based bleaching sequences, as described above under "Project Objective."

GOALS FOR FY 01:

Goal No. 1: Fiber strength retention. Identify bleaching conditions that will allow production of fully bleached southern pine pulps that retain at least 95% of the inherent fiber tensile strength of the unbleached pulp, as measured by the zero-span vs. cellulose content relationship of well bonded sheets (the "Page Protocol"): June 01

(1) Obtain suitable supply of mature (low fibril angle) southern pine roundwood obtained and chips prepared from outer portions of logs: July 30, 2000
(2) Prepare Kraft pulps over a range of yield levels for use as standard raw materials: Aug. 31, 2000
(3) Complete D(EPO)DED bleaching of standard pulps: Sept. 30, 2000
(4) Establish methods for fiber curl and microfibril angle and use to characterize standard pulp before and after D(EPO)DED bleaching: Oct. 31, 2000
(5) Establish methods for making well bonded sheets and zero span measurements and use to characterize standard pulps before and after D(EPO)DED bleaching: Nov. 30, 2000
(6) Establish methods for microscopic fiber characterization and use to characterize standard pulp before and after D(EPO)DED bleaching: Dec. 31, 2000
(7) Complete screening factorial experiments to identify bleaching variables that have the most potential for control of fiber tensile strength retention: Feb 28, 2001
(8) Complete optimizing and confirmatory factorial experiments in selected variables to identify desired bleaching conditions: June 15, 2001
(9) Complete annual report: June 30, 2001

Goal No. 2: More efficient D_0(EPO) delignification. Identify economically viable conditions for modified chlorine dioxide delignification and reinforced alkali extraction stages that will lead to a 20% reduction in extracted kappa number, relative to D(EPO) conditions representative of current commercial practice: June 01

(1) Complete literature survey to identify opportunities for further investigation and to assess the potential of D_0 stage modifications, including high consistency bleaching, use of catalysts, use of chlorate activators, and pH profiling: Aug. 31, 2000
(2) Complete screening experiments designed to select D_0 stage modifications for further research: Nov. 30, 2000
(3) Complete optimization of modified D_0 stage: May 30, 2001
(4) Complete annual report: June 30, 2001

Goal No. 3: Synergy with Project F024: Complete research activity and provide samples to support achievement of the goals of Project F024, which is directed toward improved understanding of refining, including the dependence of refining mechanisms

on fiber properties. This project is being conducted primarily within the Fiber and Paper Physics Research Unit: June 01

PROJECT SCHEDULE:

Task Description	2000 Apr - Jun	2000 July -Sept	2000 Oct - Dec	2001 Jan - Mar	2001 Apr - Jun
Goal No. 1: Fiber Strength	----------	---x			
1. Obtain RW, chips		-----x			
2. Prepare kraft pulps					
3. Complete D(EPO)DED bleaching		---x			
4. Measure curl, MFA			---x		
5. Measure zero span			-------x		
6. Complete microscope fiber characterization			-----x		
7. Complete screening bleaching factorial exps.				---------x	
8. Complete optimized bleaching exps.					------x
9. Complete confirmatory bleaching exps.					-----x
10. Complete annual report					--x
Goal No. 2: More Efficient D_O(EPO) delignification					
1. Complete literature search	----------	--------x			
2. Complete screening experiments		---	--------x		
3. Complete optimization of modified D_O stage			---	----------	--------x
4. Complete annual report					---x

DUES-FUNDED PROJECT SUMMARY

Project Title:	**Chemical Fundamentals of Bleaching**
Project Number:	**F015**
PAC:	**Chemical Pulping And Bleaching**
Project Staff:	
Principal Investigator:	**L. Lucia**
Co-Investigators:	**A. Ragauskas, D. Dimmel**
Research Support Staff:	**Sklar, Kim, Allison**
FY 00-01 Budget:	**$95,000**
Allocated as Matching Funds:	**0%**
Time Allocation:	
Principal Investigator:	**28%**
Co-Investigators:	**4%**
Research Support Staff:	**90%**
Supporting Research:	
Special Students:	**Leah Schulte**
Ph.D. Students:	**Doug Mancosky**
M.S. Students:	**Rachel Smereck, Brian Rosin, Michael Goodell**
External:	**High Selectivity Oxygen Delignification (DOE- FY01 Funds = $241,000)**

RESEARCH LINE/ROADMAP: Line # 3 - Increase the yield of kraft-pulp equivalent fiber by ten percentage points.

PROJECT OBJECTIVE: The project seeks to optimize and fully realize the advantages oxygen delignification systems possess for more selective delignification (10-20%), concomitant retained pulp strength, higher yields (at least 5%), and better bleachability (5-10% chemical consumption savings).

BENEFIT TO THE INDUSTRY/DELIVERABLES: The most important deliverables that are achievable in the current phase of this project are listed below with dates and benefits:

1. Recommendation of improved method to run oxygen stage on softwood. Aggressive oxygen stage with and without additive will be accomplished by the fall 2000 PAC meeting. Included in this research will be an investigation of the mechanism of protection afforded by phenol. The benefit of this research will be the extension of oxygen stages with minimal selectivity and/or strength loss. As part of this work, the effect of mixing on the stabilization mechanism will be evaluated by fall, 2000 and will further evaluate the fundamentals of the additive system and provide insight for anticipated mill trials. A higher strength pulp could allow replacement of softwood fiber by hardwood, with a potential for at least $1 million/yr savings if ten percent more hardwood (absolute) could be used.
2. A better fundamental understanding of the limitations of hardwood delignification will be identified, to help define how to better and more economically operate the oxygen stage. Work will include NMR analysis of the lignin structural variations occurring in

hardwood oxygen delignification stages. This work will be completed by the spring 2001 PAC meeting.

3. Recommendation of economically viable surfactants to enhance oxygen stage delignification, leading to decreased chemical consumption in subsequent stages. Results will be available for the fall 2000 PAC meeting. Preliminary results are very encouraging. Savings in chlorine dioxide consumption were estimated to result in savings of about $2 million/yr.

PROJECT STATUS:

Objective 1. Performed practical studies that investigated how oxygen delignification systems can be optimized for product yields and properties. We carefully manipulated the time, temperature, and consistency of a conventional oxygen stage to optimize the selectivity and delignification of an ordinary O stage. We also found that the greatest selectivity is achieved in the first 5-10 minutes of the stage that indicates the need to focus on manipulating this critical time window.

Objective 2. We evaluated and developed new selectivity agents including phenol and methanol. Our results showed that phenol is very effective at reducing carbohydrate damage and methanol, albeit at higher levels, introduces a level of control that may be profitable and conducive to current mill operations. We determined from very preliminary studies that commercially available surfactant additives provide the potential to enhance the overall bleaching power during an O stage.

Objective 3. PAC has expressed strong interest in analysis of the fundamental nature of the lignin component during oxygen bleaching. We are therefore interested in looking at several commercially available hardwood species to examine the nature of the lignin and assign delignification and/or selectivity differences to structural variations. We will perform several lignin isolations and characterize the lignin by Nuclear Magnetic Resonance (NMR) spectroscopy.

GOALS FOR FY 01:

(1) Evaluate various mixing conditions on the selectivity and strength of oxygen delignification: Oct 2000
(2) Evaluate effect of other additives/surfactants on oxygen delignification: Oct. 2000
(3) Determine fundamental mechanism of phenol stabilization: Mar 2001
(4) Increase focus on fundamental oxygen delignification chemistry: Mar. 2001

PROJECT SCHEDULE:

Task Descriptions	2000 Apr - Jun	2000 July - Sept	2000 Oct - Dec	2001 Jan - Mar	2001 Apr - Jun
1. Begin mixing studies	----x				
2. Evaluate strength of normal and protected pulps		----x	----x		
3. Pursue viability of surfactants		----------	----x		
4. Investigate fundamentals of O2 delignification			----------	----------x	

DUES-FUNDED PROJECT SUMMARY

Project Title:	**Closed Mill Operation**
Project Number:	**F017**
PAC:	**Chemical Pulping and Bleaching**
Project Staff:	
Principal Investigator:	**A. Rudie**
Co-Investigators:	**None**
Research Support Staff:	**Turner, White-Hughes**
FY 00-01 Budget:	**$115,000**
Allocated as Matching Funds:	**None**
Time Allocation:	
Principal Investigator:	**30%**
Co-Investigators:	**0%**
Research Support Staff:	**107%**
Supporting Research:	
Students	**Giselle Ow Yang (Ph.D.)** **Fern Peterson (M.S.00)**
External:	**Project 4288 (TIP^3)**

RESEARCH LINE/ROADMAP: Research Line 4: Reduce water usage in bleached kraft pulp production to 2,500 gallons per ton.

PROJECT OBJECTIVES:

1. Produce "Equilibrium Constants" suitable for predicting metals partitioning between wood fibers and process filtrates.
2. Evaluate factors that lead to and inhibit scale formation in bleach plants.

BENEFIT TO THE INDUSTRY/DELIVERABLES: Development of equilibrium modeling capability will enable mills to engineer for minimum scaling, troubleshoot scaling problems, and conduct routine and accurate scenario analysis for reducing effluent and closing the bleach plant. This project will produce an elementary spreadsheet equilibrium model capable of predicting metal partition in bleach plants (available by 9/00). The model will not consider chemical speciation, complex formation or NPE precipitation. The project will also provide a database for metal complex formation with black liquor organics by the end of FY 01. Elimination of scale has an estimated value to the industry of $1,000,000/yr per bleach line.

PROJECT STATUS: Both Excel spreadsheet and OLI equilibrium models were tested in FY 00 and show promise. The presence of submicroscopic precipitates in bleach filtrates was rejected. This result emphasizes the need to collect better information on metal complex formation with dissolved organics to close the mass balance. A method for determining NPE formation constants with precipitated black liquor was demonstrated. One scale sample is undergoing a thorough analysis.

GOALS FOR FY 01:

(1) Perform elevated temperature complex formation/precipitation experiments with black liquor organics and Ca^{2+}, Mg^{2+}, Ba^{2+}, and Mn^{2+}: Oct 2000
(2) Evaluate methods to collect NPE formation constants with the organics found in bleach plant filtrates (both D0 and E stages): Oct 2000
(3) Complete the initial phase development of an Excel spreadsheet bleach plant model: Oct 2000
(4) Continue validation experiments: Laboratory split-stage bleach filtrate recycle experiment, and a bleach line (TIP^3): Oct 2000
(5) Complete the analysis of at least one sample of scale and make a decision whether scale analysis is likely to provide additional insight into scale formation: Oct 2000
(6) Collect data needed for evaluation of bleach filtrate formation constants: Mar 2001

SCHEDULE:

Task Descriptions	2000 Apr - June	2000 July-Sept	2000 Oct-Dec	2001 Jan-Mar	2001 Apr-Jun
1. Complete the BL formation constants	----------	----------	--------T		
2. Evaluate the bleach filtrate formation constants a. Evaluate feasibility b. Conduct data collection	----------	----------T	----------	----------T	
3. Complete split stage model		-----T			
4. Complete preliminary Excel model		----------	---T		

DUES-FUNDED PROJECT SUMMARY

Project Title:	**High Strength, High Yield Chemical Pulps**
Project Number:	**F030**
PAC:	**Chemical Pulping and Bleaching**
Project Staff:	
Principal Investigator:	**Jian Li**
Co-Investigators:	**Don Dimmel**
Research Support Staff:	**Blair Carter, Perla Sklar, C. Courchene, White-Hughes**
FY 00-01 Budget:	**$182,000**
Allocated as Matching Funds:	**0%**
Time Allocation:	
Principal Investigator:	**33%**
Co-Investigators:	**15%**
Research Support Staff:	**133%**
Supporting Research:	
Ph.D. Students:	**J. Samp**
M.S. Students:	**X. Gu, H. Zhou**
External:	

RESEARCH LINE/ROADMAP: Line 5 - Increase Yield by 10% Absolute / Develop Modified Pulping Process.

PROJECT OBJECTIVE: The objective of this project is to significantly improve the strength properties of higher yield (up to 10%) chemical pulps to the level of current low-yield kraft pulp. The present lab research centers on suitable processes that do not require significant capital investment, which will be followed with pilot and mill trials when promising results are obtained.

BENEFIT TO THE INDUSTRY/DELIVERABLES: Higher pulp yield can significantly reduce the cost of producing chemical pulps by reducing the wood consumption per ton of pulp, and increase the production rate by reducing the organic load to chemical recovery furnace. It was estimated that a 10% yield increase in a pulp mill-limited mill would result in increased profitability of about $14 MM/yr.

Fundamental understanding of how higher chemical pulp yield will affect physical properties – This knowledge will allow member companies to estimate the impact of increasing yield on pulp strength and assist them in making strategic decisions when they modify their digester operation for the purpose of increasing pulp yield. The first discussion was published in 1999. Experimental study in progress will be completed in FY 2001 with a report to the IPST member companies.

More effective procedure to use AQ in batch kraft cooking – To be reported to PAC in Oct., 2000. If such a procedure is found, AQ dosage could be reduced by 50%, which could translate into a savings of close to $ 0.5 million per year for a 1000 ton/day mill from reduced AQ purchasing.

Fundamentals of PS/AQ interactive chemistry - To be completed in FY2001. The information generated from this work is quite fundamental in nature. Immediate

technology transfer is not expected; however, the knowledge will provide a basis for modifying AQ/PS pulping to provide better yields of a strong pulp.

PROJECT STATUS:

Physical strength evaluation and improvement for a 10% higher yield pulp – We are completing the evaluation of the physical strength of southern pine kraft pulps with 5% higher yield in FY2000.

New pilot chemical pulping system - The system was in operation starting August 1999 and was shown to the members of the Pulping and Bleaching PAC in fall 1999.

Improvement of the effectiveness of AQ in kraft cooking – This work will be completed by the end of FY2000.

Fundamentals of PS/AQ interactive chemistry - The two model compounds needed to study the PS/AQ synergism chemistry were prepared. A few manpower and equipment issues need to be resolved before we commence with studying the chemistry of at least one of the two model compounds before the end of this fiscal year.

GOALS FOR FY 01:

(1) Evaluate the proper pulping PS or AQ conditions, based on our study, to obtain higher yield pulp with good physical strength. (The information generated from this work will allow member companies to estimate the economical benefit of producing the higher yield pulp. The PS work uses high PS for the 10% yield gain, while the AQ work is aimed at pulp quality improvement): Oct 2000

(2) Identify the proper process conditions, based on our study, to obtain strong pulps from the high kappa + O_2 delignification concept. (Higher yield, 1-2%, can be obtained from this concept without sacrificing pulp strength and any capital cost.): June 2001

(3) Report the results of studying the chemistry of the first of two model systems (fundamentals of PS/AQ interactive chemistry) and make a decision on whether we need to study the second model system. (The knowledge gained about PS/AQ synergism will provide a basis for modifying AQ/PS pulping to provide better yields of a strong pulp.): March 2001

PROJECT SCHEDULE:

Task Descriptions	2000 July - Sept	2000 Oct - Dec	2001 Jan - Mar	2001 Apr - Jun
Evaluate pulping for 10% gain	----------	--------x		
Produce improved Soda-AQ pulp		----------	----------	----------x
Complete strength test		----------	----------x	
Evaluate High kappa + O_2			----------	----------x
Evaluate PS/AQ chemistry	----------	----------	----------x	

DUES-FUNDED PROJECT SUMMARY

Project Title:	**Low-Capital Bleach Plants**
Project Number:	**F045**
PAC:	**Chemical Pulping and Bleaching**
Project Staff:	
Principal Investigator:	**T. McDonough**
Co-Investigators:	**C. Courchene**
Research Support Staff:	**Vacant**
Proposed FY 00-01Budget:	**$72,000**
Allocated as Matching Funds:	**none**
Time Allocation:	
Principal Investigator:	**8%**
Co-Investigators:	**15%**
Research Support Staff:	**40%**
Supporting Research:	
Students:	**none**
External (Where Matching Is Used):	**none**

RESEARCH LINE/ROADMAP: Line #8 – Develop technologies (compatible with present pulp mill assets) to allow cost-effective expansion of kraft-pulp-equivalent fiber capacity (hardwood and softwood) by 30% without adding Tomlinson recovery boilers.

PROJECT OBJECTIVE: Identify, demonstrate, and recommend technology to allow a 30% reduction in the cost of new bleaching capacity.

BENEFIT TO THE INDUSTRY/DELIVERABLES: Successful completion of the project will substantially reduce the cost of capacity expansion in bleached kraft mills. This is a necessary condition for cost-effectiveness. Deliverables include optimum conditions and economic evaluations for the four alternatives to be examined. Based on a 30% reduction in total bleach plant capital cost, a one-time capital savings of $18 million is projected.

PROJECT STATUS: A literature survey of previously developed low-capital bleaching technologies has been prepared. It led to the conclusion that a reduction in the number of stages is the surest route to capital cost reduction, due to the corresponding reduction in the need for washers, towers, mixers, and other equipment items. Other routes to the same end include the development of bleaching sequences that require no more washers and towers than short sequences, but effectively have the same number of stages as longer sequences. Typically, these substitute short retention tubes for towers and dispense with the washers between certain stages. One likely element of such a sequence, a rapid, short retention time D_1 stage (the ClO_2 stage immediately following the first alkaline extraction stage) is being studied during the first year of work on this project. For softwood kraft pulps, the rates of brightness development and ClO_2 consumption have been monitored as a function of ClO_2 charge, pH, and temperature. The results showed that, at moderate ClO_2 charges, more than 90% of the effect of the D_1 stage can be achieved in only four minutes, provided that the temperature is high

(90°C) and the pH low (3). By the end of the current fiscal year, a similar study of hardwood kraft pulps and a second literature survey, dealing with bleaching kinetics, will have been completed. We will then have identified optimum conditions for rapid D_1 stages in the bleaching of both pulp types and will have assessed the economic potential of using such a stage. We will also have prepared a work plan for the second year of the project, based on the results of the first year's work.

GOALS FOR FY 01: We plan to focus on elimination of washers, since the washer is the single most expensive component of most bleaching stages. Two approaches are possible, one based on empirical, statistically-based optimization of partial sequences, and the other on examination of the reactions between bleaching chemicals and dissolved material carried over from the previous bleaching stage. Goals are to:

(1) Evaluate the operating costs associated with eliminating the washer between a medium consistency D_0 stage and the following (EO) stage. If a preliminary study indicates the possibility that this may be economically feasible, simultaneously optimize the conditions in the D_0 and (EO) stages of the (D_0/EO) partial sequence. Optimum conditions may differ from those that have resulted from studying these stages individually. For example, the optimum pH in the D_0 stage may be higher and the optimum oxygen dose and exit pH in the (EO) stage will likely be different. Use the optimum as a basis for economic analysis: Sept 2000

(2) Optimize and economically evaluate the (D_1/E)D_2 and (D_1/E/D_2) brightening partial sequences in a manner similar to that described above for the (D_0/EO) delignification partial sequence: Dec 2000

(3) Evaluate the (D_1/EO/D_2) partial sequence: March 2001

(4) Determine the kinetics of the reactions between ClO_2 and the material that is dissolved by the (EO) stage. Examine effects of pH, reaction time and temperature, as well as effects of conditions in the EO stage producing the dissolved material. Use the results to suggest modifications to the (EO) or D_1 stages that may facilitate washer elimination: June 2001

PROJECT SCHEDULE:

Task Description	2000 Apr - Jun	2000 July -Sept	2000 Oct - Dec	2001 Jan - Mar	2001 Apr – Jun
1. Complete preliminary study of D_O washer elimination	----------	----------x			
2. Optimize and economically evaluate $(D_1/E)D_2$ partial sequence			----------x		
3. Optimize and economically evaluate $(D_1/E/D_2)$ partial sequence				----------x	
4. Choose between studies of the (D_O/EO) and $(D_1/EO/D_2)$ partial sequences				X	
5. Evaluate (D_O/EO) or $(D_1/EO/D_2)$ partial sequence					----------x

DUES-FUNDED PROJECT SUMMARY

Project Title:	**Peroxide Delignification**
Project Number:	**F049**
PAC:	**Chemical Pulping and Bleaching**
Project Staff:	
Principal Investigator:	**Thomas J. McDonough**
Co-Principal Investigator:	**Arthur J. Ragauskas, C. Courchene**
Research Support Staff:	**A. Shaket, M. Turner**
FY 00-01 Budget:	**$90,000**
Allocated as Matching Funds:	**0%**
Time Allocation:	
Principal Investigator:	**4%**
Co-Investigators:	**15%**
Research Support Staff:	**28%**
Supporting Research:	
M.Sc.:	**D. Johnston**
Ph.D. Students:	**Nour-Eddine Djerdjouri, Ph.D.**

RESEARCH LINE/ROADMAP: Line #8. Develop technologies to allow cost-effective expansion of fiber capacity

PROJECT OBJECTIVE: Develop technologies for cost-effective, extended peroxide delignification of kraft pulp brownstock with hydrogen peroxide as the principal delignifying agent. Identify conditions that will allow the kappa number of softwood kraft pulp to be reduced to the extent that bleaching to full brightness can be completed with chlorine dioxide in a single additional stage.

BENEFIT TO THE INDUSTRY/DELIVERABLES: Successful completion of the project will reduce the industry's dependence on chlorine dioxide and oxygen for bleaching kraft pulp. This will allow mills to avoid the high capital costs associated with new chlorine dioxide generation capacity and oxygen delignification systems. The availability of such systems will also provide a route to the very low AOX levels demanded by the Cluster Rule Tier 3. Research deliverables for the fiscal year 2000-01 include (1) identification of the functional groups in lignin that are readily degraded by a state-of-the- art peroxide delignification stage and determination of which functional groups are resistant; (2) characterization of changes in residual lignin structure caused by peroxide and proposed process changes based on the resulting insight into the chemistry of the process; (3) a survey of the literature to consolidate and analyze relevant information on peroxide delignification mechanisms and technology; and (4) a proposal for further research based on the results. Reward based on a fifty percent reduction in total bleach plant capital cost is projected to be a one-time capital savings of $30 MM.

PROJECT STATUS: This is a new project that builds on the past success of F013 and F015. Research studies in F013 have demonstrated that efficient chelation followed by hydrogen peroxide delignification under forcing conditions can reduce the kappa number

of some pine pulps by 70%. Structure studies in F015 have shown that the delignification properties of hydrogen peroxide can be attributed to functional components of lignin.

GOALS FOR FY 01:

- Prepare Soda-AQ, kraft, and kraft-AQ southern pine pulps having kappa number levels of 35, 25, and 15 (P1).
- Treat pulps with selected reagents (selected from $NaBH_4$, Fremy's salt, HCHO, $NaIO_4$, peracetic acid) to induce residual lignin structural changes (P2).
- Isolate and characterize residual lignins from the unbleached and modified unbleached pulps (P3).
- Select subset (the "test pulps") representing a diversity of lignin structural types for further study (P4).
- Characterize response of the test pulps to peroxide delignification in small factorial experiments (P5).
- Correlate response to peroxide delignification with unbleached residual lignin structure (P6).
- Isolate residual lignins from the test pulps and corresponding effluents after peroxide delignification and analyze by NMR (P7).
- Correlate changes in structure with the degree of delignification to identify responsive and recalcitrant structural features (P8).

PROJECT SCHEDULE:

Task Descriptions	2000 July – Oct	2000 Oct - Dec	2001 Jan - Mar	2001 Apr-Jun
1. P1	--------x			
2. P2	------	---x		
3. Fall PAC Review		-x		
4. P3		------x		
5. P4		-x		
6. P5			---------x	
7. P6			-----x	
8. Spring PAC report and review.		--x	--x	
9. P7				--------x
10. P8.				--------x

DUES-FUNDED PROJECT SUMMARY

Project Title: Engineering Kraft Fibers
Project Number: F050
PAC: Chemical Pulping and Bleaching

Project Staff:
- **Principal Investigator:** Arthur J. Ragauskas
- **Co-Principal Investigator:** Lucian A. Lucia
- **Research Support Staff:** Dong Ho Kim

FY 00-01 Budget: $100,000
- **Allocated as Matching Funds:** 0%

Time Allocation:
- **Principal Investigator:** 20%
- **Co-Investigators:** 7%
- **Research Support Staff:** 90%

Supporting Research:
- **Ph.D. Students:** Richard Chandra

RESEARCH LINE/ROADMAP: Increase the yield of kraft-pulp equivalent fiber by ten percentage points.

PROJECT OBJECTIVE: Develop fiber technologies that will permit practical control of the acid and carbonyl content of high and low lignin content pulps. Research studies directed towards this goal will examine the use of chemical and enzymatic methods to modify these functional groups in pulp. For high lignin content pulps research studies will be directed towards modifying lignin structures and for low lignin content pulps the chemistry will be directed towards the polysaccharides. The impact of varying the acid and carbonyl content of the pulps will be studied using wet and dry strength tests, retention of papermaking chemicals, and water retention properties.

BENEFIT TO THE INDUSTRY/DELIVERABLES: Research deliverables include:
- Improve water absorbency by a factor of two for mechanical/kraft pulps targeted at tissue/fluff production
- Increase strength properties by 25%. Based on PAC input, a strength benefit taken as the ability to use more hardwood would result in about $1 MM increased profitability per every 10% more hardwood used.

PROJECT STATUS: This is a new project that builds on the past success of F047. Project F047 demonstrated that laccase, in the presence of a chemical additives, could modify selected fiber properties such as freeness.

GOALS FOR FY 01:
(1) Evaluate the acid/carbonyl group content in ECF fully bleached pulps: Sept 2000
(2) Quantify the physical effects of acid groups on mechanical and chemical pulps: Dec. 2000
(3) Evaluate the effect of chemical and enzymatic treatments on GSW and bleached kraft pulp directed at increasing the acid content of these pulps: June 2001

PROJECT SCHEDULE:

Task Descriptions	2000 July - Sept	2000 Oct - Dec	2001 Jan - Mar	2001 Apr-Jun
1. Collect and analyze ECF pulps for carboxyl and carbonyl content.	----------x			
2. Evaluate impact of carboxyl groups on pulp properties.	---	-------xx		
3. Issue fall report.		--x		
4. Apply novel enzymatic/ chemical grafting technologies on pulps.			----------x	
5. Write yearly report.				-----x
6. Optimize new pulp grafting technologies.				-----x

Chemical Recovery
Project Advisory Committee

DUES-FUNDED PROJECT SUMMARY

Project Title:	**Black Liquor Gasification Development**
Project Code:	
Project Number:	**F02801**
PAC:	**Chemical Recovery**
Project Staff:	
Principal Investigator:	**S. Sinquefield**
Co-Investigators:	**J. Frederick**
Research Support Staff:	**Jing, Sricharoenchaikul**
PAC Subcommittee	
FY 00 Budget:	**$144,000**
Allocated as Matching Funds:	**17.4%**
Time Allocation:	
Principal Investigator:	**8%**
Co-Investigators:	**50%**
Research Support Staff:	**31%**
Supporting Research:	
Special Students:	**M. Elam (M.S.)**
External (Where Matching Is Used):	**Project 4260 (DOE/Agenda 2020)**

RESEARCH LINE/ROADMAP: 8. Develop technologies (compatible with present pulp-mill assets) to allow cost-effective expansion of kraft-pulp-equivalent fiber capacity (hardwood and softwood) by 30% without adding Tomlinson recovery boilers.

PROJECT OBJECTIVE: To provide important process data at elevated pressures and temperatures, corresponding to commercial black liquor gasification conditions, and the fate of sulfur, sodium, potassium, chloride, and nitrogen versus gasification pressure, temperature, of air (or O_2)/fuel ratio, and water vapor content of the gasifier environment

BENEFIT TO THE INDUSTRY/DELIVERABLES: Efficient recovery of chemicals and energy from black liquor is a critical factor in the economics of kraft pulp manufacture. For over sixty years, this has been accomplished by burning black liquor in Tomlinson recovery boilers. Recovery boilers have been a major factor in kraft pulping's becoming the dominant process for making papermaking fiber. However, these boilers have two important limitations. They are very expensive, costing in excess of $100 million dollars. They are also relatively inefficient in converting the energy in black liquor to electrical power.

Gasification of black liquor is emerging as an alternative recovery technology. Gasification differs from combustion in that the organic matter in black liquor is converted to a fuel gas rather than burned to CO_2 and water vapor. The fuel gas consists mainly of CO and hydrogen as combustibles, with some CO_2 and water vapor present as well. One important advantage of gasification is that the fuel gas produced can be burned in a gas turbine to produce electrical energy. The hot gases exiting the

turbine are used to generate steam at high pressure to power non-condensing steam turbines to generate additional electricity. These integrated gasification – combined cycle (IGCC) power plants are capable of producing twice the electrical energy that the most efficient Tomlinson recovery boiler/steam power cycles can deliver, and about four times the U.S. industry's average, while still meeting mills' steam demands. Production of more electrical energy from black liquor reduces the need for electricity generated from fossil fuel. This reduces the amount of CO_2 released to the environment.

Gasification technology is new to black liquor, but it has been used for many years in other applications. Municipal gas works used gasification to produce a fuel gas for lighting homes before electricity took over this function. In Germany, small wood-consuming gasifiers were developed to power trucks and automobiles during World War II. The chemical industry uses gasification to produce syngas for production of organic chemicals. More recently, coal-based IGCC power plants have been installed as both industrial and commercial power plants.

Deliverables will include data and kinetic models on the impact of gasifier conditions on:

- sulfur compounds (split of S between gas and solids, form of S in gas phase and solids) at both atmospheric and elevated pressures
- fume formation and K and Cl enrichment at elevated pressures
- tars formation and destruction within the gasifier at elevated pressures
- nitrogen release and NO and NH_3 formation at elevated pressures

Projected rewards, given that a recovery boiler needs replacement, were estimated as follows: (1) $30 MM capital avoidance using gasification, and (2) increased electrical energy produced, worth $37/ton = $13 MM / yr. There is also the potential benefit of higher pulp yield (e.g., using higher sulfidity).

PROJECT STATUS: While gasification is an established technology, there are a number of black liquor-specific technical issues that need to be resolved before it will replace conventional recovery boilers. Some of these issues relate to the recovery and regeneration of pulping chemicals. Others concern gas cleanup – removal of particles and sulfur gases that can damage gas turbines. Materials of construction that can tolerate the hot, corrosive conditions within a black liquor gasifier need to be identified and evaluated.

In 1998, IPST had the opportunity to acquire a unique pilot facility to support the development of black liquor gasification. The Danish National Research Laboratory, Risoe, was offering to sell a pressurized entrained-flow reactor that they had built in 1993 for biomass gasification research. This gasifier is one of only four such reactors available worldwide. IPST purchased this gasifier at a small fraction of its $2 million initial cost. It arrived in Atlanta in June 1998 and was installed in the high bay area of the Institute's Engineering Center. It became operational approximately one year later.

The IPST pressurized gasifier can operate at pressures to 1200 psi and temperatures to 1500°C. The gas environment within the reactor can be a mixture of oxidizing and reducing gases, including water vapor. Fine particles of black liquor solids are entrained in a small fraction of the entering gas mixture and are fed into the reactor via a water-cooled injection tube. The majority of the gas enters the reactor coaxially with the gas/particle suspension.

In the reactor, the solid particles are heated rapidly (within 0.1 second) to the reactor temperature. Carbon is gasified as it reacts with O_2, CO_2, and water vapor. Sulfur, sodium, potassium, chloride, and nitrogen within the particles are volatilized. After reacting for up to 10 seconds, the particles and gases are rapidly cooled to stop the reactions. The particles are separated from the sample gas and collected for chemical analysis. The product gas is analyzed with on-line instruments. An important advantage with this type of reactor is that the fate of all of the chemical species of interest in black liquor can be investigated simultaneously in each experimental run. Table 1 shows the range of operating conditions for the pressurized gasifier.

Two research projects that will utilize the pressurized gasifier are under way. Both are aimed at providing basic data for the development of pressurized black liquor gasification technology. One is this member-dues, consortium-sponsored project to investigate the impact of pressure on the fate of sodium, sulfur, chloride, potassium, and nitrogen during gasification. The other is a DOE/Agenda 2020-sponsored project to investigate high temperature, O_2-blown, pressurized gasification of black liquor.

Table 1. Operating parameters for IPST's pressurized gasifier.

Reactor	Pressurized Entrained-Flow Reactor (PEFR)
Temperature	600 -1500°C
Pressure	1.5 – 1200 psi
Black liquor solids flow rate	0.1 - 70 g/min
Primary gas flow rate	5 – 100 l/min
Secondary gas flow rate	25 – 500 l/min
Reaction gases	N_2, O_2, $H_2O_{(v)}$, CO_2, H_2, CO, CH_4, SO_2, H_2S,...
Water vapor flow rate	8 - 170 g/min

GOALS FOR FY 01:

(1) Aaa
(2) Bbb
(3) ccc

MILESTONES:

- PEFR operational: 8/30/99
- Fate of sulfur during gasification with water vapor at atmospheric pressure: 9/30/99
- sulfur compounds (split of S between gas and solids, form of S in gas phase and solids) at elevated pressures: 6/30/00
- fume formation and K and Cl enrichment: : 6/30/00
- tars formation and destruction within the gasifier at elevated pressures: 6/30/00
- nitrogen release and NO and NH_3 formation at elevated pressures: 6/30/00

Task Descriptions	2000 Apr - Jun	2000 July - Sept	2000 Oct - Dec	2001 Jan - Mar	2001 Apr-Jun
1.	----x				
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					

DUES-FUNDED PROJECT SUMMARY

Project Title:	**Catalytic Destruction of Tars From Black Liquor Gasification**
Project Number:	**F02803**
PAC:	**Chemical Recovery**
Project Staff:	
Principal Investigator:	**K. Iisa**
Co-Investigators:	
Research Support Staff:	**V. Sricharoenchaikul**
FY 00-01 Budget:	**$20,000**
Allocated as Matching Funds:	**100%**
Time Allocation:	
Principal Investigator:	**7%**
Co-Investigators:	
Research Support Staff:	**5%**
Supporting Research:	
Special Students:	
Ph.D. Students:	
M.S. Students:	
External:	**Project 4320 (DOE - $80,000)**

RESEARCH LINE/ROADMAP: Line #8. Develop technologies (compatible with present pulp-mill assets) to allow cost-effective expansion of kraft-pulp-equivalent fiber capacity (hardwood and softwood) by 30% without adding Tomlinson recovery boilers.

PROJECT OBJECTIVES: (1) To develop catalytic tar cracking that is capable of destroying tars on an economical, sustained basis. (2) To develop economic pathways for the regeneration of deactivated tar-cracking catalysts. (3) To test the catalysts and regeneration on the pilot scale.

BENEFIT TO THE INDUSTRY/DELIVERABLES: Tars are condensable organic compounds that are formed during black liquor gasification. Depending on operating conditions, 1-5% of carbon in black liquor is converted to tars. Moreover, the tars adversely affect the processes downstream of the gasifier. Elimination of the tars is required for successful commercialization of black liquor gasification. The overall energy savings of converting from traditional use of recovery boilers to gasification may be as high as 100 trillion BTU/year. This cannot be realized unless an economical method of tar destruction is developed. The tars present approximately 1% of the carbon, and the savings based on the increase of 1% in energy production alone are approximately one trillion BTU/year.

Deliverables for FY 01:

(1) Preliminary recommendation for a catalyst.
(2) Preliminary recommendation for optimum operating conditions (temperature, gas concentrations) for catalytic tar destruction.

PROJECT STATUS: Several commercial catalysts have been prescreened for catalytic activity for the destruction of a model tar compound, and the most active catalysts were selected for further study. All of the catalysts tested so far exhibit sulfur-induced poisoning - but at varying rates. Group VIII metals seem to have better resistance to sulfur poisoning than Group X metals.

GOALS FOR FY 01:

(1) Determine the impact of alkali metals and other impurities on catalytic activity: Dec. 2000
(2) Select a catalyst and operating conditions for on-site experiments: Mar. 2001
(3) Design and construct on-site reactor: Apr. 2001
(4) Begin long-term experiments of the catalytic destruction of tars from black liquor fuel gases: May 2001

PROJECT SCHEDULE:

Task Descriptions	2000 July - Sept	2000 Oct - Dec	2001 Jan - Mar	2001 Apr - Jun
Assess impact of alkali metals on activity of selected catalysts	----------	----------x		
Assess impact of other impurities on activity of selected catalysts		-----	----------x	
Select catalyst and operating conditions for on-site reactor			-----x	
Complete design and construction of on-site reactor		----------	----------	---x
Run on-site experiments				----------

DUES-FUNDED PROJECT SUMMARY

Project Title:	**Control Of Evaporator Fouling**
Project Number:	**F032**
PAC:	**Chemical Recovery**
Project Staff:	
Principal Investigator:	**W. Schmidl**
Co-Investigators:	**S. Lien, V. Sricharoenchaikul**
Research Support Staff:	**Amundsen, Technician, GIT student researcher**
FY 00-01 Budget:	**$150,000 Includes $20,000 subcontract to GIT to provide 50% funding (salary, tuition, and indirect costs) for a GIT Ph.D. student for this project. The remaining 50% will be paid from project 4258.**
Allocated as Matching Funds:	**45%**
Time Allocation:	
Principal Investigator:	**20%**
Co-Investigators:	**10%**
Research Support Staff:	**100%**
Supporting Research:	
Special Students:	**none**
Ph.D. Students:	**Dan Euhus, and Bing Shi (at GIT)**
MS. Students:	**none**
External:	**Project 4258 (DOE-$268,000 for FY01)**

RESEARCH LINE/ROADMAP:
Improved Capital Effectiveness. 8. Develop technologies (compatible with present pulp-mill assets) to allow cost-effective expansion of kraft-pulp-equivalent fiber capacity (hardwood and softwood) by 30% without adding Tomlinson recovery boilers.

PROJECT OBJECTIVE:
For FY00, 100% of this project was matching for project 4258: ***Study of Soluble-Scale Fouling Control in High Solids Black Liquor Concentrators***. For FY01, only 45% of the budget will be matching for 4258. Therefore, new objectives have been added for the nonmatching portion.

A. Objectives for 4258/F032.

1. Obtain basic data on the solubility behavior of Na_2CO_3 and Na_2SO_4 in kraft black liquor at dry solids concentrations to 80 wt %.
2. Obtain fundamental data on the kinetics of crystallization of Na_2CO_3 and Na_2SO_4 from kraft black liquor at dry solids concentrations to 80 wt %.
3. Obtain experimental data on the rate of soluble-scale fouling of falling film high solids concentrators.

4. Develop a model for the rate of soluble-scale fouling of falling film high solids concentrators based on the basic solubility (from 1) and crystallization kinetics data (from 2) and the fouling rate data (from 3).
5. Prepare a monograph on the causes and control of soluble scale in high solids, falling film concentrators.

B. Objectives for nonmatching portion of F032.

1. Retrofit the pilot plate falling film evaporator.
2. Install a pilot tube falling film evaporator to complement the existing plate unit.
3. Prepare a member report summarizing the evaporator fouling survey.
4. Prepare a member report on the prediction of black liquor critical solids using NAELS.

BENEFIT TO THE INDUSTRY/DELIVERABLES: The overall benefit to the industry is increased capacity from existing black liquor evaporators and high solids concentrators, and / or reduced capital costs for new units. Specific deliverables for 4258/F032 and the nonmatching portion of F032 are given below. Elimination or improvement in evaporator scaling can result in increase in mill profitability of $200,000 – several million dollars per year, depending on the extent of the problem and on whether the mill is evaporator limited.

A. 4258/F032.

At the conclusion of this project (9/01), the pulp and paper industry and its suppliers will receive:

1. Basic data on the solubility and crystallization characteristics of Na_2CO_3 and Na_2SO_4 in high solids kraft black liquor.
2. A monograph to guide improvements in design and operation of high solids falling film evaporators for kraft black liquor.
3. A model with which to evaluate design improvements or operating changes. This information will provide the basis for improving the design of new high solids concentrators, for modifying the design of existing ones, and for better operating strategies to minimize Na_2CO_3 and Na_2SO_4 fouling. At or before the conclusion of this work, pilot- or full-scale trials will be proposed to evaluate the results at a mill site where soluble scale has been a major problem in the high solids concentrators.

Available now: evaporator audits to address fouling problems. This service can be arranged by contacting Wolfgang Schmidl or Jim Frederick.

B. Nonmatching portion of F032.

1. A fully instrumented pilot plate falling film evaporator will provide improved capabilities for running black liquor fouling experiments (available 10/00).
2. A single tube evaporator, capable of running in falling film or rising film mode, will enhance the versatility of the evaporator pilot plant and enable liquor fouling experiments to be performed on all common evaporator designs (available in FY02).
3. A review and evaluation of the evaporator fouling problem (available 12/00).
4. A statistical model with which to predict first and second critical solids as a function of liquor composition and temperature (available 12/00).

PROJECT STATUS:

A. Status of 4258/F032 as of the Spring 2000 PAC meeting.

1. Solubility experiments with black liquor.
   - Preliminary solubility experiments have identified many needed modifications to the equipment and operating procedures to overcome sample line plugging.
   - Liquor samples have been collected at a maximum of 66 wt.% total solids through a 60 + 15 + 2 μm filter assembly.
   - Shakedown runs to establish appropriate operating parameters and develop the capability to sample liquor at up to 80 wt.% total solids are still ongoing.
2. Crystallization experiments with inorganic solutions and black liquor.
   - Crystallization kinetics for the formation of burkeite from Na_2CO_3 + Na_2SO_4 model solutions have been determined.
   - For aqueous solutions of Na_2CO_3 + Na_2SO_4, the evaporation process can be divided into four stages: (1) nucleation of Na_2CO_3 or Na_2SO_4 that occurs at liquid-air interfaces due to surface evaporation, and subsequent crystal growth, (2) nucleation of burkeite crystals in the bulk solution due to supersaturation buildup, (3) predominantly secondary nucleation and crystal growth of burkeite crystals, and (4) nucleation and crystal growth of Na_2CO_3 and burkeite.
3. Construction and operation of a falling film pilot evaporator to obtain soluble-scale fouling rate data.
   - The evaporator pilot plant consisting of a plate falling film evaporator and an ATC (annular flow test cell) is now fully operational.
   - Water tests have been performed on the plate evaporator, and experimentally measured heat transfer data have been compared to the literature.
   - Operating procedures have been developed for both units.
4. Development of a soluble-scale fouling rate model for falling film high solids concentrators
   - A simplified three-dimensional falling film fluid flow model (isothermal, water only) has been developed that produced graphical flow field results with explainable three-dimensional effects on the velocity magnitude contours.
   - Methods to account for non-idealized flow effects have been evaluated with thin film experimental results taken from the literature.
   - Expressions were developed to estimate relations between film Reynolds number and film velocity for approximated black liquor evaporator conditions.

B. Status of the nonmatching portion of F032 as of the Spring 2000 PAC meeting

1. Modifications to the pilot plate falling film evaporator have been discussed, but no firm plans have been made.
2. Plans for a pilot tube falling film evaporator have been discussed, but the design work has not been started.
3. An evaporator fouling survey was conducted in 1997-99, and the process and liquor chemistry data have been compiled in a database. The statistical analysis of this data has not been started.
4. A statistically designed computer simulation experiment using NAELS to predict liquor critical solids for a range of compositions and temperatures is 80% complete.

GOALS FOR FY 01:

A. Goals for 4258/F032.

1. Complete the solubility work on one kraft black liquor. 10/00
2. Complete the solubility work on other kraft black liquors. 10/00
3. Complete the analysis of the solubility data. 6/01
4. Complete the crystallization experiments on one kraft black liquor. 10/00
5. Complete the crystallization experiments on other black liquors. 10/00
6. Analyze and model the crystallization data. 10/00
7. Run the pilot falling film evaporator to generate data for the fouling rate model. 6/01
8. Run the pilot falling film evaporator to evaluate the fouling rate model. 6/01
9. Incorporate heat transfer effects into the detailed computational flow model. 6/01
10. Complete the fouling rate model. 6/01
11. Start work on the detailed overall evaporator fouling model. 6/01

B. Goals for nonmatching portion of F032.

1. Complete the modifications to the pilot plate falling film evaporator. 10/00
2. Complete the design work for a pilot tube falling film evaporator. 6/01
3. Complete the statistical analysis of the evaporator fouling survey data. 10/00
4. Prepare a member report summarizing the evaporator fouling survey. 6/01
5. Complete the critical solids simulation experiment using NAELS. 10/00
6. Prepare a member report on predicting liquor critical solids using NAELS. 6/01

PROJECT SCHEDULE:

A. Schedule for 4258/F032.

Task Descriptions	2000 Apr - Jun	2000 July-Sept	2000 Oct - Dec	2001 Jan - Mar	2001 Apr-Jun
1. Complete solub. exp'ts.- one liquor	----------x				
2. Complete solub. exp'ts.- other liquors		----------x			
3. Analyze all solub. data		----------	--------x		
4. Complete cryst. exp'ts.- one liquor		----------x			
5. Complete cryst. exp'ts.- other liquors			----------	----------x	
6. Analyze and model crystallization data			----------	----------	--------x
7. Run pilot evaporator-data for fouling rate model		----------x			
8. Run pilot evaporator-to evaluate fouling rate model			----------	----------	--------x
9. Add heat transfer effects into CFD flow model		----------x			
10. Complete fouling rate model			----------	----------	--------x
11. Complete and evaluate evap. fouling model				----------	---------→

B. Schedule for nonmatching portion of F032:

Task Descriptions	2000 Apr - Jun	2000 July-Sept	2000 Oct - Dec	2001 Jan - Mar	2001 Apr-Jun
1. Complete plate evap. modification	----------	----------	------x		
2. Design tube evap.				------	----------x
3. Analyze evaporator fouling survey data	------	----------x			
4. Issue Member report on evaporator fouling survey			----------x		
5. Complete critical solids sim. exp't.	------	----------x			
6. Issue Member report on predicting critical solids			----------x		

DUES-FUNDED PROJECT SUMMARY

Project Title: Control of Non-Process Elements
Project Number: F03302
PAC: Chemical Recovery

Project Staff:
- **Principal Investigator:** P. Pfromm
- **Co-Investigators:** W. Schmidl, J. Frederick (advising)
- **Research Support Staff:** D. Taylor, Research Testing Services

FY 00-01 Budget: $78,000
- **Allocated as Matching Funds:** 0%

Time Allocation:
- **Principal Investigator:** 21% P. Pfromm
- **Co-Investigators:** 20% W. Schmidl
- **Research Support Staff:** 14% D. Taylor, $7,821 Testing Services

Supporting Research:
- **Special, Ph.D., M.S. Students:** None
- **External:** None

RESEARCH LINE/ROADMAP: Environmental Performance: 4 (primary). Reduce water usage in bleached kraft pulp production to 2,500 gallons per ton. 5 (secondary). Reduce emissions of the entire pulp and paper manufacturing process to meet Tier 3 Cluster Rule criteria while maintaining global competitiveness.

PROJECT OBJECTIVES:
1. Short term: to provide the members with a compilation of the existing NPE solubility data in a suitable form (e.g. spreadsheets, graphs).
2. Long term: to provide the members with a model for evaluating the effect of NPE's on closing up the mills.

BENEFIT TO THE INDUSTRY/DELIVERABLES: The overall benefit to the industry is the capability to analyze NPE behavior (including scaling and fouling), and predict the impact of process changes, in the kraft pulping process, bleach plant, paper machine, and chemical recovery cycle using existing process simulators; increased evaporator capacity, and decreased downtime. The specific deliverables are (1) a compilation of NPE solubility data, and (2) a model for evaluating the effect of NPE's on closing up the mills. For F032 it was estimated that elimination or improvement in evaporator scaling can result in increase in mill profitability of $200,000 – several million dollars per year, depending on the extent of the problem and on whether the mill is evaporator limited. In Project F017 elimination of scale was estimated to have a value to the industry of $1,000,000/yr per bleach line.

PROJECT STATUS: As of the spring 2000 PAC meeting:
1. The predictive capability for Ca, Mg, and Mn solubilities in green and white liquors has been investigated.

2. The direction of the project for FY01 has been changed. The project will be more fundamental in nature, with the focus on data compilation and generation. The existing NPE solubility data will be collected and tabulated, and missing data will be extracted from the literature, or generated experimentally. The creation of a private OLI database that can be interfaced with IDEAS and other process simulators is no longer the objective.

GOALS FOR FY01:

(1) Compile and tabulate existing NPE solubility data: Oct. 2000
(2) Report existing data reported to members: Oct. 2000
(3) Identify additional data that is required for model development: Oct. 2000
(4) Develop plan for obtaining or generating the additional data: Dec. 2000
(5) Coordinate NPE research efforts with Pulping & Bleaching Group: June 2001

PROJECT SCHEDULE:

Task Descriptions	2000 July - Sept	2000 Oct - Dec	2001 Jan - Mar	2001 Apr - Jun
1. Compile existing NPE solubility data.	----------X			
2. Report existing data to members (via member report).	-----	----X		
3. Identify additional data required to develop functional model.	-----	----X		
4. Develop plan to obtain and/or generate additional data.		----------X		
5. Coordinate NPE work with Pulping & Bleaching Group.		----------	----------	----------X
6. Incorporate additional NPE data into database.			----------	----------→

DUES-FUNDED PROJECT SUMMARY

Project Title:	**Methanol Formation/Emission**
Project Code:	
Project Number:	**F03303**
PAC:	**Chemical Recovery PAC**
Project Staff:	
Principal Investigator:	**J. Zhu**
Co-Investigators:	**X. Chai**
Research Support Staff:	**Heedick**
PAC Subcommittee	**none**
FY 99-00 Budget:	**$48,000**
Allocated as Matching Funds:	**0**
Time Allocation:	
Principal Investigator:	**5%**
Co-Investigators:	**15%**
Research Support Staff:	**25%**
Supporting Research:	
Special Students:	**M.S. Jeremy Thomas**
External (Where Matching Is Used):	**415701 (DOE)**

RESEARCH LINE/ROADMAP: Line – 5. Environmental Performance: Reduce emissions of the entire pulp and paper manufacturing process to meet Tier 3 Cluster Rule criteria while maintaining global competitiveness.

PROJECT OBJECTIVE: The overall objective of this work is to assist the industry in meeting the Cluster Rule VOC requirements in a timely and cost-effective manner.

- Methanol formation model development in storage tanks, evaporators, and oxygen delignification.
- Provide mills with technological guidance through mill sampling and model prediction.

DOE Sponsorship Part with NCASI and Univ. Idaho:

- Selecting mill sites, conducting mill sampling, and analyzing mill data to complete the database and software for computer model VOC prediction. NCASI's collaboration in measuring air emissions
- New predictive evaporator/stripper models will be added to the fiberline models already developed
- Full-mill process simulation. Integration of all models and the database into full-mill simulations

BENEFIT TO THE INDUSTRY/DELIVERABLES: This work will assist our industry in meeting Cluster Rule VOC requirements in a timely and cost-effective manner by providing predictive models for methanol formation. Current studies are focusing on methanol formation model development for black liquor evaporation, black liquor

storage tanks, and oxygen delignification. Based on feedback to the P.I., project reward was estimated as a one-time capital savings (cost of diffusion washer or condensate stripper) of about $20 MM.

PROJECT STATUS: Methanol emission in kraft mills is now regulated by the Cluster Rule. Understanding and predicting methanol emission can help mills to meet the requirements. Work has been completed in the following areas:

- Fast and automated techniques, protocols, and capabilities for VOC and Henry's constant measurements in mill samples (Reports I, II, and III issued)
- VOC formation model in pulping (Report IV issued)
- Database and equation of methanol Henry's constant in black liquors (Report V issued)
- Database of methanol formation in alkaline wood pulping (Report VI issued)
- Database of the Fate of HexA in alkaline pulping (Report VII issued)
-

GOALS FOR FY 01:

(1) Develop model for methanol formation in black liquor storage tanks: Dec. 00
(2) Quantify methanol formation in black liquor evaporation: Dec 01
(3) Quantify methanol formation in oxygen delignification: May 01
(4) Continue work on methanol Henry's constant database: ongoing

SCHEDULE:

Task Descriptions	2000 Apr - Jun	2000 July - Sept	2000 Oct - Dec	2001 Jan – Mar	2001 Apr- Jun
Continue work on VLE database	---------	---------	---------	---------	-------x
Quantify methanol formation (O_2 delig)	---------	---------	---------	---------	-------x
Quantify methanol formation (Storage)	---------	---------	-------x		
Measure methanol formation Evaporation (Pilot scale)	---------	---------	---------	---------	-------x
Validate model with UI	---------	---------	---------	---------	-------x

DUES-FUNDED PROJECT SUMMARY

Project Title:	**Electrolytic Causticizing of Kraft Smelt**
Project Number:	**F034**
PAC:	**Recovery**
Project Staff:	
Principal Investigator:	**P. Pfromm**
Co-Investigators:	**J. Winnick (Chem. E. Faculty, GIT)**
Research Support Staff:	**Wartena, Taylor**
Proposed FY 00-01Budget:	**$97,000**
Allocated as Matching Funds:	**0%**
Time Allocation:	
Principal Investigator:	**17%**
Co-Investigators:	**0% (no-cost)**
Research Support Staff:	**137%**
Supporting Research:	
Students:	**Wartena (GIT Ph.D.)**
External (Where Matching Is Used):	**none**

RESEARCH LINE/ROADMAP: 8. Develop technologies (compatible with present pulp-mill assets) to allow cost-effective expansion of kraft-pulp-equivalent fiber capacity by 30% without adding Tomlinson recovery boilers. 9: Process Improvements outside the Recovery Boiler, Alternate Combustion Technologies. 10. Reduce net energy consumption per ton by 30 percent compared to '97 levels.

PROJECT OBJECTIVE: Determine the thermodynamic fundamentals and address the fundamental material issues (electrodes) for a recausticizing process using electrolysis of molten kraft smelt. The smelt will be recausticized beyond the chemical equilibrium limitations.

BENEFIT TO THE INDUSTRY/DELIVERABLES: Incremental recaust capacity, new recaust technology with no lime kiln or calcium cycle, no NPE's from lime introduced, ~40% energy savings. For example, the addition of 50 tpd incremental capacity was estimated to result in an operating profit reward of about $5MM/year. A one-time capital avoidance of $22MM has also been estimated.

PROJECT STATUS: Cyclic voltammetry studies show the governing electrochemical processes, materials studies show candidates for successful inert electrodes.

GOALS FOR FY 00-01:

(1) Continue tests of electrode materials and materials of construction: Dec 2000
(2) Continue optimization of process conditions: Mar 2001
(3) Summarize the preliminary design: June 2001

MILESTONES: 1. Electrochemical studies (cyclic voltammetry, CV) to determine reaction mechanisms. Progress: CV is being used to investigate a number of electrodes,

reference electrodes, and smelt compositions. 2. Test electrode materials and materials of construction. Progress: Nickel/nickel oxide is a candidate 3. Test and optimize process conditions and hardware. Progress: hold until thermodynamics are sufficiently clear.

SCHEDULE:

Task Descriptions	2000 July – Sept	2000 Oct - Dec	2001 Jan - Mar	2001 Apr - Jun
Complete cyclic voltammetry studies	----------	----------		
Test electrode materials	----------	----------		
Conduct bulk electrolysis		---------	----------	
Complete preliminary design			----------	----------

DUES-FUNDED PROJECT SUMMARY

Project Title:	**ATR Sensor for on-line Kraft Liquor Analysis**
Project Code:	
Project Number:	**F035**
PAC:	**Chemical Recovery PAC**
Project Staff:	
Principal Investigator:	**J. Zhu**
Co-Investigators:	**X. Chai, J. Li**
Research Support Staff:	**none**
PAC Subcommittee:	**none**
FY 99-00 Budget:	**$48,000**
Allocated as Matching Funds:	**0**
Time Allocation:	
Principal Investigator:	**5%**
Co-Investigators:	**24%**
Research Support Staff:	
Supporting Research:	
Special Students:	**none**
External (Where Matching Is Used):	**none**

RESEARCH LINE/ROADMAP: Line – 12. Sensors and Process Control: Reduce pulp and paper product costs by 25% through increased productivity and improved pulp, paper, and product uniformity achieved with new developments in sensors and process controls.

- Develop on-line or off-line sensors to measure properties of interest. (See Industry Needs Survey and Agenda 2020 pathways.)

PROJECT OBJECTIVE: The objective of this project is to develop on-line/in-line sensors for simultaneously monitoring concentrations of NaOH, Na_2CO_3, and Na_2S in white and green liquors and the viscosity, solids content, and organic to inorganic ratio in black liquor in the kraft chemical recovery process. The specific objectives include:

(1) Design and fabricate the UV-ATR device suitable for kraft liquor analysis in very harsh environments.
(2) Resolve the complex spectrum for simultaneous measurements of multi-component concentrations.
(3) Finally, conduct field testing of these sensors at kraft mill sites.
(4) Demonstrate feasibility for chloride, sulfate, and potassium analysis.
(5) Demonstrate feasibility for pulping liquor analysis.

BENEFIT TO THE INDUSTRY/DELIVERABLES: An on-line caustic/carbonate/sulfide sensor would allow real-time green and white liquor monitoring and pulping liquor analysis leading to improved liquor quality and control. It was estimated that a 2.5% increase in causticizing efficiency could lead to a reward of over $2MM/year in a caustic-

limited scenario. Sensor work is also planned in the areas of chloride, sulfate, and potassium analyses.

PROJECT STATUS: A modern chemical recovery process can recover about 95% of sodium hydroxide for pulp production. Because kraft delignification rate and selectivity are strongly affected by the white liquor quality, i.e., NaOH and Na_2S concentrations, the goal of kraft recovery is to produce white liquor with high concentrations of NaOH and Na_2S and low concentrations of Na_2CO_3 and Na_2SO_4. Reliable, rapid, and accurate on-line complete analysis of white and green liquor compositions, mainly, the concentrations of hydroxide (or alkali), carbonate, and sulfide, can provide in-situ data to allow operators to better control the recausticizing process to produce high-quality white liquor to control pulp quality and reduce pulp mill upset. Unfortunately, most pulp mills all over the world rely on a classical offline titration method, i.e., ABC titration, to determine the concentration of hydroxide (or alkali), carbonate, and sulfide in white and green liquors. The reason is that the ABC titration method can be performed only offline and takes about 30 minutes to obtain results. Pulp mills can monitor the green and white liquor composition only every 2 to 4 hours and are unable to control the recausticizing operation, resulting in the loss of productivity and operation upset. Attenuated total reflection UV spectroscopy has the potential for on-line kraft liquor analysis. The sensor principle has been described in a report, laboratory demonstration has been completed, and mill site evaluation is underway at two mills.

GOALS FOR FY 01:

(1) Complete third mill demonstration on green and white liquors: Oct. 00
(2) Evaluate application to black liquor characterization: Mar. 2001
(3) Evaluate feasibility of sulfate analysis: Mar. 2001

PROJECT SCHEDULE:

Task Description	2000 Apr - Jun	2000 July -Sept	2000 Oct - Dec	2001 Jan - Mar	2001 Apr - Jun
1. Complete third mill demonstration	----------	----------	---x		
2. Evaluate application to BL	----------	----------	----------	----------x	
3. Evaluate feasibility of sulfate analysis			----------	----------x	

DUES-FUNDED PROJECT SUMMARY

Project Title:	**Particulate Formation, Deposition and Hardening**
Project Number:	**F03801**
PAC:	**Chemical Recovery**
Project Staff:	
Principal Investigator:	**S. Lien**
Co-Investigators:	**J. Frederick**
Research Support Staff:	**Technician**
FY 00-01 Budget:	**$100,000**
Allocated as Matching Funds:	**40%**
Time Allocation:	
Principal Investigator:	**58%**
Co-Investigators:	**0%**
Research Support Staff:	**41%**
Supporting Research:	
External: (Matching)	**DOE Project 4228 - Convection Pass Deposits in Recovery Boilers** **L. Baxter, Sandia National** **R. Wessel, McDermott** **H. Tran, U. of Toronto**

RESEARCH LINE/ROADMAP: Improved Capital Effectiveness. 8. Develop technologies (compatible with present pulp-mill assets) to allow cost-effective expansion of kraft-pulp-equivalent fiber capacity (hardwood and softwood) by 30% without adding Tomlinson recovery boilers.

PROJECT OBJECTIVE: The overall objective of this project is to obtain additional data and a better understanding of the factors that influence the plugging and deposition in the upper furnace of recovery boilers. This work falls into two main categories: first, measuring the sintering and deposition behavior of fine (fume) particles in the superheater, boiler bank, and economizer sections of the recovery boiler; and, second, obtaining additional data and a better understanding of the production of intermediate-sized particles (ISP) during black liquor combustion and their significance in recovery boilers. The results of this research should contribute significantly to the understanding of recovery boiler fouling and plugging.

BENEFIT TO THE INDUSTRY/DELIVERABLES: Since plugging and fouling of the heat transfer sections of the superheater and generating bank significantly limits the ability to efficiently operate the recovery boiler, understanding the formation and sintering of deposits has the potential to lead to significant reductions in operating costs and increases in production rates through the recovery boiler. Given a 50% reduction in boiler downtime due to plugging (i.e, 50% of about 1 week/yr, or 4 days/yr), the additional 4 days of production is estimated to result in a reward of about $1MM/year for a 1000 tpd boiler limited mill.

1. Characterize deposit growth and strength development mechanisms and rates and measure the development of critical deposit properties under commercial-scale conditions.
2. Validate sintering results by measurements in the boiler bank of operating recovery boilers.
3. Identify the mechanisms and rates of intermediate particle formation and deposition; the rates and mechanism of formation will be determined using a laboratory reactor to be constructed at IPST.
4. Develop algorithms that relate the data collected in Tasks 1 and 3 to recovery boiler operating parameters and other observables. These relationships will be expressed as mathematical algorithms that can be combined with a boiler model to produce an ash formation and deposit model.

PROJECT STATUS: A number of factors can limit the pulp capacity rate supported by a kraft recovery boiler, but the most important of these is normally plugging of gas passages in the superheater, boiler bank, and economizer. Previous research had raised key questions regarding the formation, properties, hardening, and removal of recovery boiler deposits. A research project, funded by DOE/Agenda 2020, began in February of 1998 to address several of these questions.

Sintering, the process of densification of porous solids, is responsible for hardening of fume deposits in kraft recovery boilers. As deposits densify, their strength increases exponentially with density, and they become more difficult to remove by sootblowing. Initially, this project focused on understanding factors that control the rate of sintering.

Recent research has detected the presence of intermediate-sized particles (ISPs) entrained in the flue gas of recovery boilers. These particles may have an important impact on the formation of deposits in the upper furnace of the recovery boiler. A new char bed reactor will be fabricated and testing performed to measure the rate of formation of these ISPs.

This project will be part of a larger overall effort aimed at understanding particle formation and deposition in recovery boilers, which is funded by the U.S. Department of Energy. The project will be carried out in collaboration with the Sandia National Lab and McDermott.

IPST's responsibilities in this project include obtaining data on:

a) the impacts of particle composition and gas composition on the rate of sintering and hardening of recovery boiler deposits, and
b) liquor-to-liquor differences in the amounts of fume and larger (10-100 micron) particles generated during burning of black liquor in-flight and on a char bed.

GOALS FOR FY 01:

1. Complete testing and analysis of data on the impact of gas phase composition on the rate of sintering of recovery boiler dusts – testing started FY99-00: Mar. 2001
2. Obtain data from the first recovery boiler on the rate of fume deposition, sintering rate, and deposit composition: Mar 2001

3. Construct a revised reactor for the formation and combustion of black liquor char. The system will also have the capability to collect and measure the particulate formed during combustion. The gas phase composition will be measured on a continuous basis to determine the rate of char combustion: Dec. 2000
4. Perform the initial test series using the char bed reactor: June 2001
5. Analyze the first set of data from the new char bed reactor.

PROJECT SCHEDULE:

Task Descriptions	2000 Apr - Jun	2000 July - Sept	2000 Oct - Dec	2001 Jan - Mar	2001 Apr-Jun
Effect of Gas Composition on Sintering					
1. Run tests	--------	----------	--------X		
2. Analyze data			----------	----------X	
Recovery Boiler Testing					
3. 1st Recovery Boiler			----------	----------X	
4. 2nd Recovery Boiler					----------
Char Bed – Intermediate Size Particle Testing					
5. Build New Reactor		----------	----------X		
6. Develop Methods			-----	----------X	
7. Run Experiments				------	----------
8. Analyze data					--------

DUES-FUNDED PROJECT SUMMARY

Project Title: Fume Sulfation Processes In Recovery Boilers

Project Number: F03804

PAC: Chemical Recovery

Project Staff:

- **Principal Investigator:** K. Iisa
- **Co-Investigators:**
- **Research Support Staff:** Jing, Sinquefield

FY 00-01 Budget: $85,000

- **Allocated as Matching Funds:** 0%

Time Allocation:

- **Principal Investigator:** 22%
- **Co-Investigators:**
- **Research Support Staff:** 70%

Supporting Research:

- **Special Students:**
- **Ph.D. Students:**
- **M.S. Students:**
- **External:**

RESEARCH LINE/ROADMAP: Line #8. Develop technologies (compatible with present pulp-mill assets) to allow cost-effective expansion of kraft-pulp-equivalent fiber capacity (hardwood and softwood) by 30% without adding Tomlinson recovery boilers.

PROJECT OBJECTIVE: Develop a kinetic model for the sulfation of alkali metal salts (Na_2CO_3, NaOH, NaCl) in recovery boilers.

BENEFIT TO THE INDUSTRY/DELIVERABLES: The results of this subproject together with other parts of the F038 project will result in a better understanding of fume formation and deposit sintering mechanisms. This will translate into reduced downtime and improved thermal efficiency of recovery boilers. Given a 50% reduction in boiler downtime due to plugging (i.e., 50% of about 1 week/yr, or 4 days/yr), the additional 4 days of production is estimated to result in a reward of about $1MM/year for a 1000 tpd boiler-limited mill. Deliverables for FY 01 include: (1) Kinetic data and expressions for the sulfation of sodium salts (Na_2CO_3, NaCl, NaOH) in the vapor and condensed phase, and (2) establishing a basis for assessing if it is possible to obtain low (near-zero) SO_2 emissions while providing desirable fume properties.

PROJECT STATUS: A crucial factor affecting both the stickiness and strength of recovery boilers is the chloride content of the deposits. Deposits with even high K but low Cl content do not harden. Therefore, the key to controlling recovery boiler plugging and fouling is to obtain fume with a low Cl content. The fume Cl content can be kept low by keeping Cl volatilization low or by enhancing NaCl/KCl conversion to Na_2SO_4. The objectives of the proposed research are to define optimum conditions for producing fume particles with low Cl content and at the same time keeping SO_2 emissions acceptable.

By the end of fiscal year F99-00, we expect to have completed a prescreening of sodium salt sulfation reactions to determine their relative rates.

GOALS FOR FY 01:

(1) Screen all sulfation reactions (NaCl, Na_2CO_3, and NaOH); decide which reaction to study first: June 2000
(2) Complete experimental work for sulfation of first salt: Sept. 2000
(3) Complete experimental work for sulfation of second salt: Dec. 2000
(4) Complete experimental work for sulfation of third salt: Mar. 2001
(5) Develop kinetic expressions: May 2001
(6) Complete annual report: June 2001

PROJECT SCHEDULE:

Task Descriptions	2000 Apr-June	2000 July - Sept	2000 Oct - Dec	2001 Jan - Mar	2001 Apr - Jun
Screen reactions	----------x				
Complete sulfation of first salt		----------x			
Complete sulfation of second salt			----------x		
Complete sulfation of third salt				----------x	
Develop kinetic expressions				------	-------x
Issue annual report					-x

DUES-FUNDED PROJECT SUMMARY

Project Title: Fate Of Heavy Metals In Recovery Boilers
Project Number: F03805
PAC: Chemical Recovery

Project Staff
- **Principal Investigator:** K. Iisa
- **Co-Investigators:**
- **Research Support Staff:** Jing

FY 00-01 Budget: $50,000
- **Allocated as Matching Funds:** 0%

Time Allocation:
- **Principal Investigator:** 12%
- **Co-Investigators:**
- **Research Support Staff:** 49%

Supporting Research:
- **Special Students:**
- **Ph.D. Students:**
- **M.S. Students:**
- **External:**

RESEARCH LINE/ROADMAP: Line #5. Reduce emissions of the entire pulp and paper manufacturing process to meet Tier 3 Cluster Rule criteria while maintaining global competitiveness.

PROJECT OBJECTIVE: The objectives are (1) to assess the impact of recovery boiler operating conditions on the heavy metals emissions and (2) to assess the relationship between metal inputs and purges to/from the liquor cycle on metals emissions.

BENEFIT TO THE INDUSTRY/DELIVERABLES: As a result of this research, fundamental information on the behavior of heavy metals during combustion in a recovery boiler will be obtained. The information can be used to optimize the operating conditions in a recovery boiler to reduce the volatilization of the heavy metals in the boiler, thereby making it possible to reduce heavy metal emissions from recovery boilers without the need for upgrading existing air pollution control equipment. Potential savings relate to a mill not having to upgrade the electrostatic precipitator, allowing a one-time capital saving of at least $2 million.

FY 01 deliverables:
- Laboratory data on the effect of black liquor metal content on heavy metals volatilization.
- Quantification of the relationship between metals concentrations in the liquor cycle and metals emissions from recovery boilers and lime kilns.
- Assessment of strategies for controlling heavy metal accumulation and emissions.

PROJECT STATUS: Eleven heavy metals are hazardous air pollutants (HAP) as defined by EPA, and their emissions are limited. The heavy metals that are emitted from boilers are in the form of submicron fume particles that are formed by the vaporization of the metals in the furnace and subsequent condensation in the cooler parts of the boiler. The results during the first year of this project have shown that Pb and Cd are highly volatile regardless of operating conditions. Others, such as Mn, Ni, Cr, and Be, are of low volatility, and their volatilization can be suppressed by keeping the conditions reducing and temperature low. Arsenic is of medium volatility, and its emissions can, to a limited extent, be affected by operating conditions.

GOALS FOR FY 01:

(1) Determine the impact of heavy metals content on volatilization: Oct. 2000
(2) Determine relationship between metal inputs and purges to/from the liquor cycle on heavy metals emissions: May 2001

PROJECT SCHEDULE:

Task Descriptions	2000 July - Sept	2000 Oct - Dec	2001 Jan - Mar	2001 Apr - Jun
Evaluate impact of heavy metals content on volatilization.	----------	----x		
Evaluate impact of purges on heavy metals emissions		----------	----------	--------x
Issue project report				-------x

Corrosion Control
Project Advisory Committee

DUES-FUNDED PROJECT SUMMARY

Project Title:	**Mechanisms and Prevention of Stress-Assisted Waterside Corrosion in Recovery Boilers**
Project Number:	**F036**
PAC:	**Corrosion Control**
Project Staff:	
Principal Investigator:	**Preet Singh**
Co-Investigators:	**Research Support Staff: Greg Fonder, Jamshad Mahmood**
FY 2000-01 Budget:	**$30,000**
Allocated as Matching Funds:	**0%**
Time Allocation:	
Principal Investigator:	**5%**
Co-Investigators:	
Research Support Staff:	**24%**
Supporting Research:	
Special Students:	**N/A**
External (Where Matching Is Used):	**N/A**

RESEARCH LINE/ROADMAP: Research Line #8 - Improve operations and control of current recovery boilers. Research Line #9 - Reduce lifetime costs of construction by 30% through innovative technologies.

PROJECT OBJECTIVES: Gather information needed regarding Stress Assisted Corrosion (SAC) in the pulp and paper industry through industry wide questionnaire and make IPST member companies aware of this potential problem in their recovery boilers. Initial efforts in this project will be used to propose a bigger project to DOE to address remedial measures related to water treatment, chemical cleaning, operating practices, and improved materials of construction to mitigate SAC in recovery boilers. This DFRC project will provide industry-specific support to the 2020 research project at Oak Ridge National Laboratories. The project will build on previous research in the utility industry to study the mechanism of stress-assisted corrosion in recovery boilers and its relationship to attachment weld design.

BENEFIT TO THE INDUSTRY / DELIVERABLES: Any water leak in a recovery boiler is a potential explosion threat. SAC is one of the failures that cannot be detected during regular fireside inspections using ultrasonic thickness measurements or visual examinations. This project will make member companies more aware of this problem so as to avoid any accident. Deliverables include:

1. Initial survey results have indicated that over 35% mills are not aware of or are not inspecting their boilers for SAC. Initial project report to the member companies will make member companies aware of this boiler safety related problem. This report will cover summary of SAC related failures, general locations to be inspected and extent of problems in the Pulp and Paper industry.

2. Metallurgical features associated with weld related SAC failures. If we find certain microstructure more prone, steps can be taken to suggest welding procedures to avoid such microstructural changes in the waterwall tubes.

It was projected that future savings could be up to $ 1MM/boiler/year (money now spent to upgrade boiler).

PROJECT STATUS: Corrosion or cracks in the boiler tubes can lead to water leaks in the boiler that can potentially lead to boiler explosion. One of the insidious corrosion mechanisms responsible for boiler corrosion is from the waterside and is called stress-assisted corrosion cracking (SAC). SAC of waterwall tubes poses safety and operation-related problems to kraft recovery boilers. Generally, these types of failures are associated with attachment welds where structures are welded onto waterwall tubes. If not detected, during non-destructive inspections earlier, the failure of tubes results in pinhole leaks on the cold side or casing side of the tube, near attachment welds. SAC cracking is experienced throughout the boilers. In 1999-00 the project was geared toward doing an initial survey on the SAC problem and awareness of it in the industry. Results from this survey are coming in, and we are getting a better understanding of the extent of awareness as well as the type of waterside failures in the industry. The second task was to perform failure analysis on boiler tubes with SAC and investigate any metallurgical changes in failed tubes, due to welding, that may be responsible for SAC failure. This task is being carried out at IPST as well as at ORNL where a MPLUS project was started in collaboration with a member company. Failed tubes from other member companies are being obtained.

Eliminating stress-assisted waterside corrosion in recovery boilers would eliminate the cost of replacing boiler bottoms where waterside corrosion under external attachment welds has produced deep internal fissures. It would also eliminate the risk of tube ruptures propagating from internal cracks. This project is geared toward resolving these questions by doing appropriate research work at IPST and taking the lead to begin an organized effort, on a bigger scale, by involving experts from the pulp and paper industry and other industries, as well as other researchers, such as those from Oak Ridge National Laboratory.

GOALS FOR FY 2000-01:

(1) Complete an MPLUS project with ORNL to do initial failure analysis to investigate any metallurgical changes associated with SAC in kraft recovery boilers: Sept. 2000

(2) Complete analysis of replies from industry-wide SAC survey and report to PAC and member companies: Sept 2000

(3) Organize a national colloquium on SAC in recovery and other utility boilers so as to learn from the past experience of personnel involved in similar problems in other industries and also to focus our efforts to solve this problem. (Colloquium in July 2000, Report by September 2000)

(4) Report on occurrence of stress-assisted waterside corrosion in recovery boilers and on its correlation with feedwater treatment practices, chemical cleaning practices and attachment weld design: Dec 2000

(5) Confirm role of microstructure to SAC susceptibility in best boiler water environment (Either through literature or by experiments): April 2001

SCHEDULE:

Task Descriptions	2000 Apr - Jun	2000 July - Sept	2000 Oct - Dec	2001 Jan - Mar	2001 Apr-Jun
Analyze results from questionnaire	--	X			
Complete initial failure analysis	----------	---------X			
Organize national colloquium		X			
Discuss Project progress with PAC (Fall)			---X		
Report to PAC					----------X

DUES-FUNDED PROJECT SUMMARY

Project Title:	**Corrosivity of Black Liquors**
Project Number:	**F037**
PAC:	**Corrosion Control**
Project Staff:	
Principal Investigator:	**Preet Singh**
Co-Investigators:	
Research Support Staff:	**Assoc. Eng., Greg Fonder** **Jamshad Mahmood**
PAC Subcommittee	**N/A**
FY 00-01 Budget:	**$40,000**
Allocated as Matching Funds:	**0%**
Time Allocation:	
Principal Investigator:	**10%**
Co-Investigators:	
Research Support Staff:	**24%**
Supporting Research:	
Special Students:	**Adolfo Anaya (M.S. thesis)**
External (Where Matching Is Used):	

RESEARCH LINE/ROADMAP: Research Line #9 - Reduce lifetime costs of construction by 30% through innovative technologies.

PROJECT OBJECTIVES:

1. To correlate corrosivity of different black liquor condensates to allow mills to choose mitigation technology.
2. To participate in a larger "digester project" funded by DOE at ORNL and work on tasks mutually agreed upon by PAC.
    - Evaluate on-line electrochemical probes for digester applications
3. To study stress corrosion cracking susceptibility of commonly used alloys in selected black liquor condensates.

BENEFIT TO THE INDUSTRY / DELIVERABLES:

1. Rank materials based on their performance in black liquor condensates.
2. Predict susceptibility of commonly used alloys in different black liquor condensates to stress corrosion cracking

A reward up to $0.5 MM /year was estimated based on using less expensive anodic protection versus more expensive spraying.

PROJECT STATUS: Corrosion and stress corrosion cracking in the vapor phase of digesters, flash tanks, evaporator domes, auxiliary equipment, and storage tanks create problems in pulp mills. Some of these problems are related to the use of less-resistant materials due to a lack of knowledge of the environment in vapor phase areas.

Condensates of black liquors from certain wood species are considerably more corrosive than others. Some work ha been done ranking different materials in particular mill equipment; however, the environment in these cases has not been characterized. Organic acids have generally been suspected as the cause of such attack. Our preliminary work has indicated that the condensates have low pH and contain a number of volatile organics as well as sulfur-containing gases. Controlled tests for corrosion and stress corrosion cracking will be conducted in condensates from different black liquors or mill condensates. Materials selection strategies that will mitigate vapor phase/condensate corrosion will be offered. These suggestions will take into account the different wood species being pulped in a given mill.

GOALS FOR FY 2000 01:

(1) Conduct experiments on the correlation between electrochemical noise signal and the corrosion rates in a pilot digester:: Dec 2000
(2) Investigate the performance of different commonly used alloys in selected black liquor condensates: June 2001
(3) Conduct experimental work to investigate the stress corrosion cracking susceptibility of commonly used alloys in black liquor condensates: June 2001

PROJECT SCHEDULE:

Task Descriptions	2000 Apr - Jun	2000 July - Sept	2000 Oct - Dec	2001 Jan - Mar	2001 Apr-Jun
Modify digester to install corrosion probes	----------X				
Experiments with probes		----------	----------X		
Meet with ORNL to collaborate on their project		-----X			
Experiments in black liquor		----------	----------	----------	---------X
Report to PAC				----------X	

DUES-FUNDED PROJECT SUMMARY

Project Title:	**Cost of Corrosion and Related Maintenance in the Pulp and Paper Industry**
Project Number:	**F051**
PAC:	**Corrosion Control**
Project Staff:	
Principal Investigator:	**Preet Singh**
Co-Investigators:	
Research Support Staff:	**Assoc. Eng., Post-Doctoral Fellow**
FY 00-01 Budget:	**$50,000**
Allocated as Matching Funds:	**100%**
Time Allocation:	
Principal Investigator:	**15%**
Co-Investigators:	
Research Support Staff:	**20%**
Supporting Research:	
Special Students:	**N/A**
External (Where Matching Will Be Used):	**(DOE 2020 Project)**

RESEARCH LINE/ROADMAP: Research Line #9 - Reduce lifetime costs of construction by 30% through innovative technologies.

PROJECT OBJECTIVES: The project goal is to calculate total corrosion and maintenance-related costs in the pulp and paper industry in North America. The survey will focus on maintenance costs for all process streams in the pulp and paper mill, and rank each area according to the impact that equipment failure might have on the mill's overall productivity. The objective is to provide a model to make cost-effective decisions on corrosion prevention methods.

BENEFIT TO THE INDUSTRY/ DELIVERABLES: Estimated cost of corrosion in the pulp and paper industry is roughly $750 Million. A significant portion of these costs is avoidable by using known corrosion prevention technologies. This project will help calculate total corrosion related costs (direct and indirect). The model developed in this project will estimate the effect of corrosion in particular process unit on overall productivity. This will also allow industry to make cost effective decisions on corrosion mitigation technologies. A sensitivity study will allow industry managers, materials and corrosion scientists, and the funding agencies for materials research to focus on the major materials related needs of the industry. The study will include both installation and fabrication of new equipment as well as repair costs for the existing equipment into consideration.

Deliverables for this project are:

1. Total cost of corrosion and related maintenance and avoidable costs in the pulp and paper industry.
2. Compilation of corrosion costs for individual process units.
3. Prioritization of maintenance of equipment based on their impact on the overall pulp and/or paper production.
4. Model to calculate effect of new material selection or other corrosion mitigation technology on cost of corrosion and overall productivity.

The project return has been estimated at over $3mm/year.

PROJECT STATUS: According to an NBS survey in 1986, carried out by Battelle, the national corrosion costs for the USA were estimated to be about 4.2% of GDP. Taking inflation into consideration, the cost will be about $300 billion per year in 1999. Similar estimates have been made for the pulp and paper industry. According to an article in Pulp and Paper Magazine, the cost of corrosion in the pulp and paper mills of North America alone is over $1 billion. According to the same source, the cost of corrosion and maintenance in certain mills can be as high as $100/ton of paper produced. These are rough estimates and vary considerably from one mill to another. Millions of dollars are spent on maintenance and repairs to avoid corrosion-related failures in the pulp and paper industry. The impact of corrosion failure in certain areas of the mill is much more expensive than in others. Similar economic impact studies have been done for other processes in the pulp and paper industry; however it has not been done for corrosion and materials- related costs.

We propose to conduct a scientific survey of corrosion and maintenance costs in the pulp and paper industry in North America. The survey will focus on the maintenance costs for all process streams in the pulp and paper mill, and rank each area according to the impact that a failure of equipment might have on overall mill productivity. This survey report will help the industry managers, materials and corrosion scientists, and the funding agencies for materials research to focus on the major materials related-needs of the industry. Mills representing different age, pulping processes, product grades, and mill locations will be selected. The study will take into consideration both installation and fabrication of new equipment as well as repair costs for the existing equipment.

To carry out such an investigation, we will collaborate with different paper companies. Our first target will be IPST Member Companies. Cooperation of specific mills will be essential in this survey, as most of the data will be collected from their local records. Prof. Joe Payer of the Case Western Reserve University will act as a consultant for this study. He will provide his prior experience in conducting such surveys for the Department of Transportation as well as for the 1986 NBS national study conducted at Battelle. However, this survey will be different from such surveys, as it will focus on the pulp and paper industry only. We will collaborate with experts in economic modeling, consultants, and university researchers to analyze the collected data in a scientific way that will be easy to use. Some of the paper companies may have carried out similar studies for their mills. We will seek their collaboration to learn from their experiences and will try to incorporate their data into this study.

GOALS FOR FY 00-01:

(1) Identify reliable sources of data and start collecting relevant data from mills: Sept 2000

(2) Contact two different mills and start collecting corrosion related data. Finish data collection for two mills: June 2001
(3) Start modeling efforts to do sensitivity study on impact of corrosion in particular areas on overall productivity. Get initial model working: Jan 2001
(4) Discuss initial results with PAC: March 2001

SCHEDULE:

Task Descriptions	2000 Apr - Jun	2000 July - Sept	2000 Oct - Dec	2001 Jan - Mar	2001 Apr-Jun
Identify candidate mills for data		---	---X		
Start with initial model			----------	-X	
Collect data and analyze		---	----------	----------	----------X
Report initial results to PAC				-----X	

DUES-FUNDED PROJECT SUMMARY

Project Title:	**Corrosion Above Cut-Line in Kraft Recovery Boilers and On-line Fireside-Corrosion Monitoring Sensor**
Project Number:	**F052**
PAC:	**Corrosion Control**
Project Staff:	
Principal Investigator:	**Preet Singh**
Co-Investigators:	**Greg Fonder**
Research Support Staff:	**Assoc. Eng., Jamshad Mahmood,**
FY 00-01 Budget:	**$160,000**
Allocated as Matching Funds:	**0%**
Time Allocation:	
Principal Investigator:	**20%**
Co-Investigators:	**50%**
Research Support Staff:	**65%**
Supporting Research:	
Special Students:	**N/A**
External (Where Matching Is Used):	

RESEARCH LINE/ROADMAP: Research Line #9 - Reduce lifetime costs of construction by 30% through innovative technologies; Research Line # 8 - Improve operation and control of current recovery boilers; Research Line #12- Sensors and Control

PROJECT OBJECTIVES:

1. Improve safety and increase operating life of kraft recovery boiler equipment by understanding corrosion mechanisms, properly selecting construction materials, and identifying suitable process conditions.
2. Develop an on-line corrosion probe that is easy to install to measure the corrosion rate of waterwall tubes in kraft recovery boilers.

BENEFIT TO THE INDUSTRY/DELIVERABLES: Any water leak in the recovery boiler can potentially cause a boiler explosion. Therefore, corrosion control of waterwall tubes in the furnace is very important for safe operation of kraft recovery boilers. Results from this project will benefit the industry in the following way.

- Provide an understanding of local environments in the upper furnace of recovery boilers that causes above cut-line corrosion. Such environments were considered to be oxidizing and therefore not very corrosive to the carbon steel.

Loss in tube thickness measured during annual inspection is an average corrosion rate and does not indicate possible high corrosion rates during process upsets. On-line corrosion monitoring in kraft recovery boilers will allow boiler operators to correlate tube wastage to process upsets or other process controls.

Deliverables:
1. Environment characterization in areas with cut line corrosion phenomenon.
2. Mechanism of above cut-line attack in high temperature environments.
3. New strategies in terms of new materials for thermal spray or weld-overlay to mitigate the above cut-line attack.
4. Standard method to collect and send recovery boiler gas samples to lab for regular analysis in cost-effective way.
5. On-line probe to monitor fireside corrosion in the lower furnace of kraft recovery boilers that will give short-term corrosivity of boiler environment at waterwall surface.
6. Testing of probe in superheater and economizer areas of the boiler.

Reward (not having cut-line corrosion; sensor benefits) was estimated at over $3MM/year .

PROJECT STATUS: The lower furnace area of kraft recovery boilers has a reduced sulfidizing environment. Carbon steel undergoes sulfidation in such environments. Carbon steel waterwall tubes undergo sulfidation at unacceptable rates, especially in boilers working at high pressure. Composite tubes with an outer stainless steel shell were introduced to protect against general high-temperature corrosion from the fireside. Tubes are generally used up to the secondary or tertiary air-port level, above which carbon steel is used as the waterwall material. This was done because it was assumed that the environment is oxidizing above secondary air ports. Stainless steel has performed well against the general sulfidation attack. However, in recent years, due to changes in operating conditions or due to other unknown factors, different corrosion phenomenon have been experienced. One of them is above cut-line attack. Accelerated corrosion attack has been reported to occur on carbon steel in the area where the stainless steel waterwall is welded with the carbon steel. As the attack is greater on the carbon steel than the stainless steel, this phenomenon has been attributed to galvanic effect. However, galvanic attack is very localized and does not explain accelerated corrosion attack ten to twenty feet above composite tubes.

Spray coatings and weld-overlay have been used as a fix for this problem, but the problem is not fully mitigated as the above cut-line attack can move higher to the new junction. In this project, we will develop a systematic understanding of this phenomenon so that it can be effectively mitigated and not merely transferred elsewhere. Local gaseous environments at the waterwall surface in boilers with this problem will be characterized in two representative boilers to understand the local corrosive environments. For galvanic effect to operate, electrolyte is required. Sulfide scale on the waterwall tubes as well as frozen smelt can act as solid electrolytes. However, properties of sulfide scale can be changed by altering its composition. This can be achieved by introducing alloying elements that alter the sulfide scale conductivity.

The corrosion rate of waterwall tubes can only be measured by measuring the tube thickness during boiler shutdown, which typically is carried out annually. Corrosion rates measured during annual shutdown give the average corrosion rate and do not tell about the variations in corrosion conditions during boiler upsets or operational changes. In-situ corrosion monitoring sensors are needed to monitor the corrosion rate while the boiler is operating, and in relatively short periods of time. Generally, boiler operators have to wait until the annual shutdown to find out the effects of any operational change on fireside corrosion in their boiler. However, on-line corrosion monitoring sensors will allow boiler operators to relate the process changes to the corrosion rate of boiler tube material. This

information will enable boiler operators to make timely decisions and adjust the operating parameters accordingly.

Initial work was carried out, as a part of a DOE-funded project on corrosivity of kraft recovery boilers at IPST, to develop and evaluate a corrosion-monitoring probe using an electrical resistance technique. Results of the laboratory tests and exposure of the corrosion probe in a recovery boiler have shown that the probe signal correlates well with the corrosion of the probe element. However, this technology needs further development to use it to monitor the corrosion rates in different areas of the kraft recovery boiler. Presently, the probe can indicate if the corrosion rates have changed over a given period. However, absolute corrosion rates cannot be monitored with confidence. Further work is needed to correlate the probe signal to the corrosion rate of the waterwall tube material. About 20 percent of total project efforts and funds will be devoted to develop this corrosion probe.

GOALS FOR FY 00-01:

(1) Identify two boilers with above cut-line corrosion: Aug 2000
(2) Characterize corrosive environment in the first boiler that experiences above cut-line corrosion and identify such areas through previous tube thickness inspections: Sept 2000.
(3) Characterize environments below and above high corrosion areas to identify changes in the gas compositions along the boiler length: Mar 2001
(4) Characterize corrosive environment in second boiler which experience above cut-line corrosion and have identified such areas through previous tube thickness inspections: Mar 2001
(5) Identify methods to store and ship recovery boiler gas samples to lab for later analysis Extend this technology to other parts of boilers susceptible to high temperature gaseous corrosion. Second year

Work on this project will also be aimed at developing a corrosion-monitoring probe that can be used throughout the boiler to measure the fireside corrosion.

(1) Establish relationship of probe signal to the corrosion rate of the probe element over a long time period: Jan 2001
(2) Application of the above results to correlate the probe signal with the corrosion rate of tube materials in each selected area of the boiler: March 2001
(3) Develop and test the corrosion probes in different parts of a kraft recovery boiler. June 2001

PROJECT SCHEDULE:

Task Descriptions	2000 Apr - Jun	2000 July - Sept	2000 Oct - Dec	2001 Jan - Mar	2001 Apr-Jun
Install sampling ports in two boilers		----------	----X		
Complete online characterization of corrosive environment in Boiler # 1		-----	----------	----X	
Give report to PAC - Fall			--X		
Complete online characterization of corrosive environment in Boiler # 2			----	---------- X	
Establish relationship of probe signal with the corrosion rate		----------	----------	----X	
Establish the effect of the deposited smelt		--	----------	----X	
Complete data analysis			----------	----X	
Complete field testing of probes				----------	----------X
Complete final analysis and written report to member companies				-	----------X

Forest Biology
Project Advisory Committee

DUES-FUNDED PROJECT SUMMARY

Project Title:	**Mass Clonal Propagation of Improved Conifers**
Project Number:	**F010**
PAC:	**Forest Biology**
Project Staff:	
Faculty:	**J. Pullman, J. Cairney, G. Peter, J. MacKay**
Research Support Staff:	**Johns, Perfetti, Vales, Zhang, Halprin, Wong. temporary help, summer intern**
FY 00-01 Budget:	**$460,000**
Allocated as Matching Funds:	**6%**
Time Allocation:	
Faculty:	**132%**
Research Support Staff:	**339%**
Supporting Research:	
MS Students:	**Tyler Miller, Alicia Stephens**
Ph.D. Students	**V. Ciavatta, S. Van Winkle**
External:	**Project 4130 – FY99 TIP^3 $126,401**
	Project 4286 – FY99 TIP^3 $ 46,128

RESEARCH LINE/ROADMAP: Line #1 – Improve the Fiber Productivity of North American Lands so that they are Competitive in the World Pulpwood Market

PROJECT OBJECTIVE: Develop reliable cell and tissue culture systems for the mass clonal propagation of genetically improved softwoods. Focus is on loblolly pine.

BENEFIT TO INDUSTRY/DELIVERABLES: Implementation of efficient and low cost somatic embryogenesis technology will lower the cost of wood while increasing wood uniformity. In addition, somatic embryogenesis will provide some of the tools necessary for advanced tree breeding and genetic engineering. This long-term project has several forms of deliverables that include the following.

1) Improved protocols for individual steps in the process above
2) Strategies for improving embryo development protocols.
3) Analyses of natural and somatic embryos to help IPST and member companies develop and test hypotheses for the improvement of somatic embryogenesis protocols.
4) Gene isolation, identification, and potential function knowledge leading to improved somatic embryogenesis protocols.
5) Gene sequences useful for genetic modification of plants.

Given a wood fiber cost savings company-wide of $15/finished metric ton of product, a reward was estimated to be about $14MM/yr over five mills, each with 50% of the fiber supply softwood.

PROJECT STATUS:

Initiation – We have developed a medium that is outside of recent issued patents that produces 15.8% initiation. In addition, two factors have been identified that improve initiation further; patent protection is being sought for these factors. These factors now need to be optimized and blended into our current system.

Maintenance – PAC requested initiation capture experiments to improve our rate of obtaining cultures for maturation.

Maturation – Our somatic embryos currently develop to a stage of 8-9.1 as measured by appearance, size, dry weight, germination ability, and gene activity. A major focus of this program is to advance development beyond stage 9.1. Our metals and amino acid analyses, germination studies, suspensor studies, and gene expression studies generated several hypotheses for the improvement of somatic embryos. Many of these studies need to be repeated for a second set of trees and need to be tested in tissue culture media.

Germination – Our somatic embryos currently germinate to form somatic seedlings but at low rates. Two approaches appear to be relevant for germination improvement: 1) to advance embryo maturation to a later stage, and 2) to develop post-maturation treatment(s) to improve germination of our immature somatic embryo.

Molecular Biology Tools to Improve Somatic Embryogenesis – IPST has developed a large collection of stage-specific genes involved in embryo and suspensor development. We are evaluating the activity of hundreds of genes over development using DNA arrays. We have improved the reliability and speed of the process by a number of technical means plus the addition of sensitive assay and data processing equipment. This research provides four major benefits: 1) develops hypotheses to improve embryo development protocols, 2) provides methods to evaluate and compare somatic embryos with natural seed embryos, 3) provides molecular markers which can help access achievement of critical developmental points through embryo growth, and 4) identify new genes that lead to improved knowledge of embryogenesis and may be used to genetically engineer trees for improved value. We have begun cataloging gene activity over the course of development and have developed a number of hypotheses for embryo quality improvement. These are now being tested. We have identified a number of gene expression markers for embryo development and these are being patented.

MILESTONES:FY 2000-2001: (PAC has agreed on a series of long-term tissue culture step targets that are necessary to commercialize somatic embryogenesis. Steps with a * have been achieved, steps in bold are active research areas.)

Targets	Achievements
1) Initiation – 35%	**16%**
2) Culture Survival (Capture) – 50%	**20-30%**
3) Growth in Liquid Maintenance Media (MM) – 80%*	Included in #2
4) Cryogenic Storage and Survival of Cultures – 80%*	74%
5) Yield of Cotyledonary Embryos / ml Cells – 25+*	≥190
6) Genotypes producing Cotyledonary Embryos from MM - 50%	56-83%
7) Embryo stage (maturity) – Stage 9.4	**8-9.1**
8) Liquid Cultures that Produce Cotyledonary Embryos – 50%	50-80%
9) Germination of Cotyledonary Embryos – 75%	**0-50%**
10) Acclimation (seedling growth in-vivo) – 80% of Germinants*	95%
11) Genotypes from MM that produce Acclimated Germinants – 50%	**15-20%**

GOALS FOR FY 2000-2001: (See approximate completion times for each goal on the project schedule section.)

1. Improve initiation protocol to meet target of 35%.
    A. Optimize Factors A and B in initiation Media
    B. Run, evaluate and report summer initiation experiments.
    C. Run, evaluate and report winter initiation experiments.
    D. Verify if initiation rates can be improved by applying findings from studies of genetic and environmental variability of initiation.
    E. Investigate factors responsible for low survival of initiated cultures, and use information to improve survival and capture of cultures
2. Improve quality and uniformity of early-stage embryos in liquid media.
    A. Improve uniformity of early-stage embryos in liquid media.
    B. Develop analysis-based maintenance medium (metals, amino acids, sugars)
3. Metals analysis of somatic and zygotic embryos.
    A. Analyze somatic embryos grown on analysis-based media modifications.
    B. Continue media improvements (all steps of the protocol) based on metal analyses.
4. Evaluate new cultures for performance in improved protocols.
5. Improve maturation protocol.
    A. Continue work on analysis-based improvements (metals, amino acids, sugars)
    B. Continue work on ABA / osmoticant control of embryo quality
    C. Re-implement, improve, and standardize ABA quantification method for somatic & zygotic tissues
    D. Test hypotheses generated by gene expression analysis and profiling
6. Improve germination to target level of 75%
    A. Optimize method for partial drying
7. Continue work on analysis of osmoticants in zygotic embryos and female gametophyte tissue.
    A. amino acids – analyze zygotic and female gametophyte tissues for second tree
    B. sugars – work out system, identify unknown compounds, analyze zygotic and female gametophyte tissue across development for first tree.
8. Investigate suspensor development in somatic embryogenic lines.
    A. Compare somatic and zygotic suspensor tissue with regard to development and gene expression profiles.
    B. Investigate the relationship between suspensor morphology and suspensor gene expression profiles as a function of variation in tissue culture media.
9. Gene expression during conifer embryogenesis.
    A. Develop reliable quantification tools / protocols for assaying gene expression
    B. Identify marker genes, which are active at specific stages of zygotic embryo development.
    C. Use cDNA markers for embryo development and correlate with performance of somatic embryo lines.
    D. Begin to determine where (anatomically) in the embryo specific genes are expressed.
    E. Develop new expanded cDNA arrays by adding newly cloned pine embryogenic genes and other pine cDNAs.
    F. Establish a database of transcript levels for 500 genes over the course of loblolly pine somatic and zygotic embryo development.

G. Use transcript-profiling arrays to assess gene expression patterns in response to tissue culture treatments. This is part of a continuous cycle of improvement.
   i. relate to embryo quality
   ii. compare to zygotic embryo gene activity patterns
H. Investigate function and role of major embryo-expressed genes

PROJECT SCHEDULE:

Task Descriptions	2000 July - Sept	2000 Oct - Dec	2001 Jan - Mar	2001 Apr – Jun
1-A	----------	----------		
1-B	----------	----------		
1-C			----------	----------
1-D	----------	----------		
1-E	----	----------	-----	
2-A	----------	----------	----------	----------
2-B	----------	----------	----------	----------
3-A	----------			
3-B	----------	----------		
4-A		----------	----------	
5-A	----------	----------	----------	----------
5-B	----------	----------		
5-C	----------	----------	----------	----------
5-D	----------	----------	----------	----------
6-A	----------	----------		
7-A	----------			
7-B	----------	----------		
8-A	----------	----------		
8-B		----------	----------	----------
9-A	----------			
9-B	----------	----------		
9-C	----------	----------	----------	
9-D				
9-E		----------	----------	
9-F	----------	----------	----------	----------
9-G	----------	----------		
9-H-i	----------	----------	----------	----------
9-H-ii	----------	----------	----------	----------
9-I	----------	----------	----------	----------

DUES-FUNDED PROJECT SUMMARY

Project Title:	**Fundamental Biological Mechanisms: Improved Stem Growth Rates & Fiber Properties**
Project Number:	**F011**
PAC:	**Forest Biology**
Project Staff:	
Principal Investigator:	**G. Peter**
Co-Investigators:	**J. MacKay**
Research Support Staff:	**Zhang**
Proposed FY 00-01 Budget:	**$119,000**
Allocated as Matching Funds:	**25%**
Time Allocation:	
Principal Investigator:	**19 %**
Co-Investigators:	**00 %**
Research Support Staff:	**91 %**
Supporting Research:	
Students:	**Brian Crow (MS), Andrew Cox (MS), Greg Delozier (Ph.D.)**
External (Where Matching Is Used):	**Projects 4292 (TIP3), 4293 (TIP3), 4294 (TIP3)**

RESEARCH LINES: Lines #2- Develop fibers with properties similar to or better than northern softwood and Eucalyptus that can be grown in most regions of North America.

PROJECT OBJECTIVE: Investigate molecular mechanisms that regulate cellulose synthesis and cellulose organization to devise strategies to lower the microfibril angle of juvenile wood.

BENEFIT TO THE INDUSTRY/DELIVERABLES: Low microfibril angle and low coarseness are two of the more important fiber properties that make fiber quality in northern softwoods and Eucalyptus superior to fiber from US pine plantations.

- Creating loblolly pine trees that grow faster and that produce more tracheids/volume of wood with lower wood costs and potentially lower coarseness will improve the uniformity of fiber sources for papermaking.
- Understanding the molecular mechanisms that control the angle with which cellulose deposits, microfibril angle (MFA), will help us create trees that have decreased MFA in juvenile wood. Lowering the MFA in juvenile wood from 30 to 10 degrees will increase paper sheet tensile strength more than two-fold.

Deliverables include the following:

1. Analysis of celA expression during cambial division, xylem cell elongation and differentiation. (Fall and Spring PAC)

2. CelA cDNA sequences (Fall PAC)
3. Vectors for epitope tagged celA overexpression
4. Transformed cell lines with epitope tagged celA (Winter 00-01)
5. Transformed cell lines with GFP-tubulin (Fall PAC)
6. Method for analysis of microtubule dynamics (Fall/Winter 00)

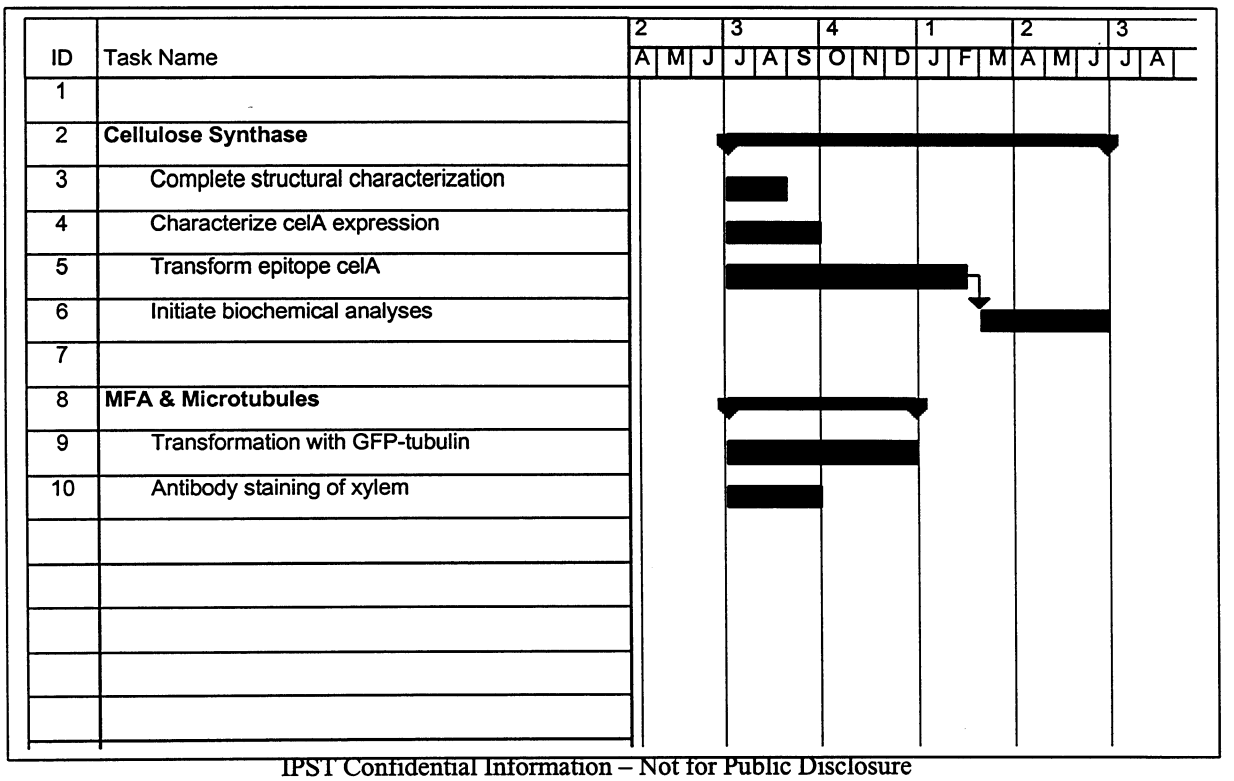
PROJECT STATUS: Anticipated status of the project at the end of the current fiscal year (June 30, 2000): Seven-nine classes of celA cDNAs have been isolated and partially structurally characterized. Full-length cDNAs for the two classes that are most abundant will be ready for construct building. GFP-tubulin constructs will be ready for transformation into pine. Earlywood xylem tissues will have been collected for more detailed analysis of celA expression.

GOALS FOR FY 00-01: ((See approximate completion times for each goal on the project schedule section.)

(1) Complete structural characterization of celA cDNAs,
(2) Characterize the expression of celA cDNAs in loblolly pine secondary xylem,
(3) Create transgenic pine expressing epitope tagged celA and GFP-tubulin,
(4) Validate and analyze celA transgenics and initiate biochemical analyses of cellulose synthase subunits from somatic embryo cultures;
(5) Develop method for determining microtubule organization and dynamics during secondary xylem differentiation.

MILESTONES: 1) Complete characterization of celA structure and expression during secondary xylem formation, 2) create transgenic pines expressing epitope tagged celAs; 3) create transgenic pine expressing GFP-tubulin; and 4) develop method for analysis of microtubule organization during xylem differentiation.

PROJECT SCHEDULE:



DUES-FUNDED PROJECT SUMMARY

Project Title:	**Trees with Easily Pulped Lignin through New Genetic Selection Methods**
Project Number:	**F046**
PAC:	**Forest Biology and Chemical Pulping and Bleaching**
Project Staff:	
Principal Investigators:	**J. MacKay, D. Dimmel**
Technical Staff:	**Perfetti, Sklar**
FY 00-01Budget:	**$71,000**
Allocated as Matching Funds:	**none**
Time Allocation:	
Principal Investigators:	**20%**
Co-Investigators:	
Research Support Staff:	**50%**
Supporting Research	
Students:	**none**
External (Where Matching Is Used):	**none**
External funds:	USDA - $80,000 per year (Oct.99–Oct.01)

RESEARCH LINE/ROADMAP: Improved Productivity – Research Line 2: Develop fibers with properties similar to or better than northern softwood and Eucalyptus that can be grown in most regions of North America (Develop softwood trees that are easily pulped)

PROJECT OBJECTIVE: The proposed research is aimed at developing and exploiting the benefits of trees that contain easily extracted lignin and/or less lignin. Our approach relies primarily on the exploitation of naturally occurring variability at the gene level rather than genetic engineering of trees. The immediate goal of this project is to establish the value of CAD-deficient pine trees as the raw material for producing pulps and to understand the relationship between structure and reactivity of lignin in CAD-deficient pine trees. A long-term objective, which relies in part on developments being reported in other research groups, is to identify other methods for genetic modification of lignin synthesis that would decrease the lignin content while increasing the cellulose content of wood.

BENEFIT TO THE INDUSTRY / DELIVERABLES: Trees that contain modified lignin will allow pulping to be conducted more rapidly or under milder conditions, leading to increased productivity, stronger pulps (because of less fiber damage), lower energy and bleaching costs, fewer bleaching by-products, and, possibly, pulping processes that rely less on sulfur.

Deliverables from this project include the characterization of potential benefits of CAD-deficient pines for pulping and bleaching. As an initial estimate, given a pulp-mill-limited softwood line that can now cook in 10% less time, the reward was estimated to be about $9mm/yr. The research will also develop genetic fingerprinting methods to identify partially CAD-deficient trees within loblolly pine breeding populations. Finally the project

will identify appropriate strategies to develop clonal populations of CAD-deficient loblolly pine.

PROJECT STATUS: This project links genetic and chemical (pulping and bleaching) investigations to accelerate the discovery and characterize the genetic variation in lignin that occurs naturally in populations of forest trees. The last step in the biosynthesis of lignin precursors is catalyzed by the enzyme cinnamyl alcohol dehydrogenase (CAD). By genetic selection, two types of mutant trees are available: partially and totally CAD-deficient (CAD-). In conjunction with North Carolina State University, we have established that a totally CAD- tree is much more easily delignified than a normal pine tree. This effect appears to be principally related to the unusual building blocks that make up the polymeric lignin in totally CAD- wood. Because of the building blocks, the tree produces a lower molecular weight lignin, which we believe solubilizes more rapidly than normal lignin because fewer fragmentation reactions are needed. In addition, the totally CAD- pulp is about as easy to bleach as a normal pulp that has the same lignin content. All of these conclusions are based on very small-scale reactions: 0.5 g cooks and 2 g bleaching experiments.

Under DFRC project F046, started in July 1999, we changed our focus to explore the pulping and bleaching of partially CAD-deficient loblolly pines and the corresponding lignin structure. Partially deficient trees show an increase of 14% in debarked volume after 4 years of growth in comparison to the normal tree. Several small-scale soda, kraft, and soda/AQ cooks have been performed on 4-year-old partially CAD- and normal pine chips. We observed no kappa number differences for identical cooks of the two pines done with different chemical charges and H-factors. However, in larger (1-Kg) kraft cooks, we have observed that the partially CAD-deficient wood pulps about 15-25% faster than normal wood. The remainder of FY 2000 will be directed at further establishing this trend with other partially CAD- wood samples and other types of pulping. We will be working with IPST member companies to get older partially CAD- trees to study.

Genetic screening has identified seven mother-trees that have the gene that causes the CAD-deficiency (the cad-n1 gene). More trees will be screened; however, the trees we have identified are expected to be sufficient to lead to the identification of mature partially CAD-deficient trees for pulping experiments and wood chemistry studies. DNA sequence variation has been identified in the cad gene that will allow us to utilize DNA fingerprinting in search of such trees in the appropriate families. We are developing the procedures for DNA fingerprinting of cad genes in the mother-trees that we identified. Controlled crosses between a few of these mother-trees were carried out in winter 2000, and we seek to do more controlled pollination in 2001.

GOALS FOR FY 01: The goal for the coming year is to continue pulping and bleaching studies of partially CAD-deficient trees, with a growing emphasis on mature wood. To meet these goals, we must identify mature partially deficient trees, and this will require the completion of genetic screening and DNA fingerprinting steps. We aim to include trees from diverse genetic backgrounds for the best determination of the potential benefits of these trees. Trees from several families will be tested in small-scale pulping studies, and larger scale pulping and bleaching will be carried out on selected trees only. We will also begin investigating the potential of completely CAD-deficient trees in non

inbred families. Specifics related to the above goals over the period of April 2000 to June 2001 can be found in the PROJECT SCHEDULE (next).

(1) GENETIC SCREENING SELECTION
   a) Identify progeny tests with families containing partially CAD- mature trees
   b) Identify and select partially CAD- mature trees by fingerprinting
(2) PULPING AND BLEACHING STUDIES
   a) Complete pulping and bleaching of juvenile partially CAD- trees.
   b) Obtain wood core samples from partially CAD- mature trees in several families for preliminary pulping studies
   c) Conduct pulping studies of mature trees: small scale to assess benefits for pulping
   d) Determine composition of wood in mature partially CAD-deficient trees
   e) Obtain larger wood samples: selected trees based upon small scale pulping
   f) Start larger scale pulping of mature trees
(3) EVALUATION OF NON-INBRED TOTALLY CAD- TREES BY SEEDLINGS
   a) Grow seedlings
   b) Lignin analyses, from seedlings
   c) Plan/ carry out more controlled crosses

PROJECT SCHEDULE: Major tasks of the project that are proposed for the coming fiscal year.

	Task Descriptions	2000 Apr-Jun	2000 July-Sep	2000 Oct-Dec	2001 Jan-Mar	2001 Apr-Jun
1a)	Identify families with part. CAD- mature trees	----------	--------x			
2b)	Select partially Cad- mature trees		----------	----x		
2a)	Pulping, bleaching: juvenile part. CAD- woods	----------	--------x			
2b)	Wood core samples from mature trees			------	--x	
2c)	Pulping studies of mature trees: small scale				--------x	
2d)	Determine composition of wood in mature partially CAD-deficient trees					--------x
2e)	Obtain larger wood samples: selected trees				------x	
2f)	Start pulping of mature trees: larger scale				---	----------
3a)	Non inbred totally CAD- seedlings: - Grow	----------	----------	--------x		
3b)	- Lignin analyses				--------x	
3c)	Plan/ carry out more controlled crosses			---	--------x	

Paper Physics
Project Advisory Committee

DUES-FUNDED PROJECT SUMMARY

Project Title: Acoustic Separation
Project Number: F008
PAC: Paper Physics

Project Staf
Principal Investigator: F. Ahrens
Co-Investigators: T. Patterson
Research Support Staff: Jong, Bose

FY 00-01 Budget: $106,000
Allocated as Matching Funds: 100%

Time Allocation:
Principal Investigator: TBD
Co-Investigators: TBD
Research Support Staff: 60%

Supporting Research:
Special Students: none
Ph.D. Students: none
MS. Students: none
External: 4190 (TIP^3 - $147k, SEP - $50k)
4183 (DOE Agenda 2020 - $150k)

RESEARCH LINE/ROADMAP:

- #4 — Reduced water usage
- #7 — Increase paper machine PRODUCTIVITY on BREAKTHROUGH DEWATERING
- #11 — Improve PRODUCT performance to COST ratio
- #12 — Reduce pulp and paper PRODUCT COSTs through new developments in SENSORs and process control
- #13 — Reduce/control contaminants in recycled fiber pulp using BREAKTHROUGH (separation) technologies

PROJECT OBJECTIVE: To perform a mill demonstration of ultrasonic water clarification.

BENEFIT TO THE INDUSTRY/DELIVERABLES: Based upon an economic analysis performed by Beloit Corporation last summer, the Acoustic Clarifier should yield 65% savings in capital installation COSTs and 35% savings in operating COSTs over traditional clarification technologies, such as dissolved air flotation.

PROJECT STATUS: All efforts for the last 6 months have been focused on starting the mill trials this summer. As of first week of May 2000, the pilot scale clarifier had been designed and approximately half of the parts were installed in the mill, with the remainder of the parts scheduled for installation by the end of May. We are working with two transducer manufacturers to provide high EFFICIENCY transducers that will survive the pressure and temperature of the mill. Several small prototype units from both vendors have been tested in the laboratory to aid the vendors with their final designs. We expect to receive the final transducers for the clarifier in early June.

GOALS FOR FY 01: By the fall 2000 PAC meeting, we expect to have the pilot clarifier operating at the mill site, and to be able to provide at least preliminary separation and

electrical EFFICIENCY data. By Spring 2000, we hope to have finished the data analysis for the summer/fall 2000 trials, and also to have evaluated an alternate cylindrical transducer design. Finally, we would like to have a new Industrial Partner to provide COMMERCIALIZATION for the technology by Spring 2000.

PROJECT SCHEDULE:

Task Descriptions	2000 Apr - Jun	2000 July - Sept	2000 Oct - Dec	2001 Jan - Mar	2001 Apr-Jun
1. Installation of Pilot Equipment at Mill Site	--------x				
2. Debugging and Calibrating of Pilot Equipment	------x				
3. Trials at Mill	--	----------x			
4. Data Analysis		----------	----------x		
5. Alternate (Cylindrical) Design Experiments in Lab				----------x	
6. Propose improvements to Pilot Equipment				----------x	
7. Write yearly report					----------x
8. Search for new Industrial Partner	----------	----------	----------	----------	----------x

DUES-FUNDED PROJECT SUMMARY

Project Title: **Fundamentals Of Dimensional Stability**
Project Number: **F020**
PAC: **Paper Physics**

Project Staff:
Principal Investigator: **D. Coffin**
Research Support Staff: **K. Collins, B. Hojjatie**

Proposed FY 00-01 Budget: **$92,000**
Allocated as Matching Funds: **0%**

Time Allocation:
Principal Investigator: **20%**
Research Support Staff: **83%**

RESEARCH LINE/ROADMAP: Line #11 Improve the ratio of product performance to cost for pulp and paper products by 25% by developing: models, algorithms, and functional samples of fibrous structures and coatings that describe and demonstrate improved convertibility and end-use performance and break-through papermaking and coating processes that can produce innovative webs with greater uniformity than those produced by current processes.

PROJECT OBJECTIVE: Create a science-based understanding of cockle, by developing mechanisms, and establishing the dependence of cockle on paper and process parameters. Member Companies can use the project report, the cockle guide, IPST tools, and expertise to identify, characterize, and eliminate cockle problems.

BENEFIT TO THE INDUSTRY/DELIVERABLES: The efficiency with which companies can determine causes of cockle problems and eliminate these problems should be greatly enhanced by using the results of this project. Great savings can be realized if paper does not have to be downgraded or discarded because of cockle. For example, it was estimated that for every 1% increase in overall machine efficiency, increased return of about $0.5MM would be achieved.

This project has provided mechanisms of cockle (F020 report #2, '96) and methodology to characterize cockle (IPST Shadow Moiré System, and report 12/00). The dependency of cockle to paper and process properties as determined from lab studies will be given in a report (6/00), and the current project will climax in a cockle guide (6/00). During the next fiscal year mill application of this knowledge will be sought.

PROJECT STATUS: We have established that cockle can be considered as a local buckling of the sheet due to nonuniform shrinkage/expansion. Preliminary results indicate that restraint during drying is the main factor that affects severity of cockle. Current studies are investigating the affect of other process and sheet parameters on the severity of cockle. Drying studies are being conducted jointly with project F02102. A technical guide that identifies different types of cockles and sheet wrinkles is being assembled. This guide will provide mechanisms for the different cockles and possible corrective actions to eliminate the cockles. We are trying to establish closer ties to Member Companys' issues and set-up possible mill trials.

GOALS FOR FY 00-01: The following list provides the remaining goals of the project. By the Fall PAC meeting much progress should be made on the handsheet studies, outline of the cockle guide, and the cockle characterization report.

(1) Establish sheet making procedures and methods for handsheet studies: July 2000
(2) Complete report on tools and methods for cockle characterization: Dec. 2000
(3) Complete cockle studies: Dec 2000
(4) Complete drying studies: Apr 2001
(5) Issue final report: June 2001
(6) Issue cockle guide: June 2001

PROJECT SCHEDULE:

Task Descriptions	2000 July - Sept	2000 Oct - Dec	2001 Jan - Mar	2001 Apr - Jun
1. Complete lab studies on cockle during drying	---------- X			
2. Complete lab studies on cockle in converting	----------	----------X		
3. Issue cockle measurement report	----------	----------X		
4. Work with F02102	----------	----------	----------X	
5. Analyze results		----------	----------	--X
6. Issue cockle guide	----------	----------	----------	----------X
7. Issue final report				----------X

DUES-FUNDED PROJECT SUMMARY

Project Title: MICROMECHANICS OF FIBER NETWORKS
Project Number: F023
PAC: End-Use, Paper Physics and Converting

Project Staff:
- **Principal Investigator:** Martin Ostoja-Starzewski
- **Co-Investigators:** none
- **Research Support Staff:** none

PAC Subcommittee A. Colasurdo, W. Hamad, E. Stewart

FY 99-00 Budget: $60,000
- **Allocated as Matching Funds:** 0%

Time Allocation:
- **Principal Investigator:** 35%
- **Co-Investigators:** 0%
- **Research Support Staff:** none

Supporting Research:
- **Special Students:** Jaime Castro (Ph.D.)
- **External (Where Matching Is Used):** N/A

RESEARCH LINE/ROADMAP: Line #11 - Improve the ratio of product performance to cost for pulp and paper products by 25% by developing: models, algorithms, and functional samples of fibrous structures and coatings that describe and demonstrate improved convertibility and end-use performance and breakthrough papermaking and coating processes that can produce innovative webs with greater uniformity than those produced by current processes.

PROJECT OBJECTIVE: To develop an understanding of the relation of the macroscopic (scales of centimeters to meters) to the microscopic (fiber and fibril scales) mechanical properties of paper. The main focus is on a quantitative assessment of paper's stiffness, strength, and fracture in the MD-CD plane from single fiber and fiber-fiber bond properties as well as formation.

BENEFIT TO THE INDUSTRY/DELIVERABLES:
1. 2-D and 3-D network models of elasticity and strength (progressive damage phenomena) of fiber networks with rigid (or flexible) fiber-fiber bonds that run on a personal computer – successive versions developed in '98 and '99. These models rigorously account for a multitude of microscale interactions (fiber axial, bending and torsional responses) and network formation (flocculation) structure. This model, once mill-validated, could be used to optimize sheet structure for maximum stiffness and strength, e.g., to identify optimal location inside the sheet for fiber-fiber bonding agents.
2. Experimental assessment of the effect of turbulence of fiber suspensions (on the wire during the paper making process) on the statistical variability of in-plane elastic and

strength properties of paper; appropriate statistical models were also developed - '98, '99, and '00. Results can be used to assess degree to which nonuniformity adversely affects strength properties and hence degree to which uniformity improvement could increase sheet strength.

3. Stress wave propagation (longitudinal and flexural) in paper is found to be strongly sensitive to formation; however, paper basis weight fluctuations have different influences than elastic moduli variations and non-uniformity of cross-sectional properties - fall '99 and spring '00. This work, once validated, would allow identification of sheet flutter propensity as a function of sheet uniformity.

PROJECT STATUS:

1. The fiber network model has been extended to accommodate several thousand fibers (all the interactions handled according to the laws of mechanics). This model (in both the 2-D and 3-D versions) allows computation of elasticity as well as strength/fracture (progressive damage phenomena) of fiber networks with rigid (or flexible fiber-fiber bonds) while accounting for the formation (flocculation) structure. The program runs on personal computers or UNIX workstations. It is a powerful tool to study internal stresses and global responses of low-basis-weight paper. Verification of the model was conducted by experiments on handsheets.
2. Several aspects of (micro)mechanics of paper, using the above model, were examined: (i) the uniform strain assumption has been shown not to produce good paper stiffness or strength predictions – the effect being especially dependent on formation; (ii) an explanation of special elastic orthotropy of paper has been advanced; (iii) optimal paper thickness for highest bending stiffness was computed for a model problem; (iv) the flexible bonds have been demonstrated not only to lower the effective stiffness but also to increase the ductility of paper; (v) coupling of single fiber's axial and torsional responses (at non-zero fibril angles) has a strong influence on the paper's MD-CD plane shear moduli.
3. Mechanics of a single fiber as a helically-wound, elastic, multi-layer composite have been investigated; explicit formulas were derived.
4. A wide range of dependencies of stiffness and strength properties on specimen size, aspect ratio, and loading/boundary conditions have been examined experimentally.
5. Statistical, multi-scale correlation structure of stiffness and strength of paper – primarily due to the turbulence on wire - has been investigated. Quasi-isotropic random fields (i.e., random processes in the MD-CD plane) and covariograms have been identified as basic models able to grasp this structure.
6. Effects of formation on propagation of longitudinal and flexural stress waves in paper were studied mathematically. It was found that imperfection in mass density has different effects on stress waves than imperfection in elastic moduli or cross sectional area of paper. Depending on the wavelength, there is a tendency to diffuse the resonance frequency around that of a reference (idealized), homogeneous material.

GOALS FOR FY 01:

1. Develop correlation functions of statistical non-uniformity of paper by further experiments: Oct 2000
2. Further validation of the fiber network model, and preparation of a user's guide for computer operation of the model: May 2001

PROJECT SCHEDULE:

Task Descriptions	2000 Apr - Jun	2000 July - Sept	2000 Oct - Dec	2001 Jan - Mar	2001 Apr-Jun
1.Develop models of of paper's random non-uniformity by experiments	-----	-----	-----		
2. Model validation, and issue user's guide			-----	-----	-----

DUES-FUNDED PROJECT SUMMARY

Project Title: IMPROVING THE REFINING OF CHEMICAL PULPS

Project Number: F024

PAC: PAPER PHYSICS

Project Staff:

- **Principal Investigator:** John Waterhouse
- **Co-Investigators:** Hiroki Nanko
- **Research Support Staff:** open position

Proposed FY 00-01 Budget: $76,000

- **Allocated as Matching Funds:** none

Time Allocation:

- **Principal Investigator:** 25%
- **Co-Investigators:** 5%
- **Research Support Staff:** 52%

Supporting Research:

- **Students:** -
- **External (Where Matching Is Used):** -

RESEARCH LINE/ROADMAP: Line #11 – Improve the ratio of product performance to cost for pulp and paper products by 25%.

PROJECT OBJECTIVE: Determine the optimum balance of changes in fiber structure produced by refining (internal and external changes in fiber structure, fines production, fiber "cutting", and curl control) to develop strength-related properties of new pulps produced under Project F013 – Pulping and Bleaching Unit with the least impact on the pulps water removal characteristics (fiber saturation point).

BENEFIT TO THE INDUSTRY/DELIVERABLES: Improved refining strategies for producing the most desirable changes in fiber structure for traditional pulps and those resulting from new pulping and bleaching processes. Improved strategies should result in savings in raw materials (basis weight reduction), enhanced paper machine productivity (water removal), and energy savings in refining. For example, a 10% reduction in the fiber saturation point should result in a 2.5% increase in web dryness out of the press section (10% production increase). Also, refiner optimization should allow a reduction in product density, potentially translating into use of less fiber to produce the same caliper. Deliverables are listed as follows:

1. Recommendations for measuring a pulp's propensity to "cutting".
2. Refining strategies for optimizing the property development and water removal characteristics of a pulp
3. Recommendations concerning the impact of new pulping and bleaching methods on refining (in cooperation and conjunction with F013 – Pulping and Bleaching Unit).
4. Report on low consistency (3% to 7%) – particulate turbulent flow refining potential.

PROJECT STATUS: In conjunction with the Pulping and Bleaching Unit Project F013, we have compared the refining characteristics of kraft and kraft-oxygen delignified pulps subjected to the bleaching sequences CED and DED. The main thrust of this investigation has been to examine the fiber's propensity to "cutting" as well as the impact of curl generation during pulping. Never-dried fiber strength as measured by never-dried zero span strength is proposed as a measure of a fiber's propensity to "cutting". The ratio of never-dried to dried zero-span strength measures the loss in never-dried fiber strength with respect to dried zero-span strength, to minimize the effects of fiber curl.

A reduction in wet fiber strength is found with both decreasing kappa number and the bleaching sequences DED and CED. Wet fiber strength has also been measured on some commercial pulps. Wet fiber strength reduction of a commercial bleached kraft pulp was produced using bulk HCl treatment. When this pulp was refined in a 12-inch Sprout Waldron disk refiner, substantial fiber "cutting" was found when compared with an untreated control.

Attempts are currently being made by the end of this fiscal year to increase the severity of refining in the 12-in Sprout Waldron disk refiner such that fiber "cutting" can be induced in commercial pulps without chemical treatment.

GOALS FOR FY 00-01:

1. Determine the impact of a pulp's propensity to "cutting" on water removal and paper property development for selected mill pulps: Oct 2000
2. Evaluate the real-world refining performance of pulps produced by Project F013 - Pulping and Bleaching Unit: March 2001
3. Evaluate the potential of using low consistency-particulate turbulent flow for producing energy efficient changes in fiber structure: March 2001

PROJECT SCHEDULE:

Task Descriptions	2000 July - Sept	2000 Oct - Dec	2001 Jan - Mar	2001 Apr - Jun
Improve refiner	---------M			
Obtain refiner plates	-------			
Conduct refiner trials – prod. Pulps	-------			
Conduct refiner trials – F013 pulps		----------	--------	
Evaluate pulp and handsheets	-M	-------- M	---	-------M
Design & build refiner cell		----------M		
Conduct refining trials			----------M	
Present findings and write reports		P	R P	R M

* will include light and transmission microscopy and FQA services as required.
P denotes presentation, R denotes either status or progress report, M denotes milestone.

DUES-FUNDED PROJECT SUMMARY

Project Title: **Fundamentals of Fiber Bonding**
Project Number: **F025**
PAC: **Paper Physics**

Project Staff:
Principal Investigator: **Hiroki Nanko**
Co-Investigators: **none**
Research Support Staff: **Shaobo Pan**

Proposed FY 00-01Budget: **$105.000**
Allocated as Matching Funds: **0 %**

Time Allocation:
Principal Investigator: **35%**
Research Support Staff: **34%**

Supporting Research:
Students: **Michelyn McNeal (M.S.)**

RESEARCH LINE/ROADMAP:
Line 11 – Improve the ratio of product performance to cost for pulp and paper products by 25% by developing:

- Models, algorithms, and functional samples of fibrous structures and coatings that describe and demonstrate improved convertibility and end-use performance
- Breakthrough papermaking and coating processes that can produce innovative webs with greater uniformity than that achieved by current processes.

PROJECT OBJECTIVE: Investigate the mechanism of bond strength enhancement due to dry strength agents based on microscopic observations of (1) adsorption of bonding agents to the fiber, (2) location of bonding agents in the sheet, and (3) bond breakage, combined with bond strength measurements.

BENEFIT TO THE INDUSTRY/DELIVERABLES: Insight for designing new bonding agents. A visualization technique for bonding agents that can be used as a diagnostic tool for wet end operation and for the analysis of paper products. If $5/ton were saved on strength agent cost and if filler content were increase 5% absolute, the reward was estimated to be about $2MM/yr.

PROJECT STATUS: A visualization method of bonding agents by transmission electron microscope was developed. This method at high magnification clearly shows the molecular conformation of bonding agents when they are adsorbed to the pulp surface. The method has been applied to various polyacrylamides (PAMs), cationic guar, and cationic starches under various wet-end conditions. This method will provide new insights into the conformation of strength-enhancing polymers in aqueous solution as well as polymer/fiber interactions.

GOALS FOR FY 00-01:

(1) Complete development of the visualization techniques for various bonding agents in paper, including polyacrylamides, starches, and gums: Oct 2000
(2) Understand the effects of dosage, charge density of the polymers, conductivity, shear of mixing, charge density of the pulp etc., for these polymers: Oct 2000
(3) Complete handsheet study to measure the sheet strength in relation to dosage, conductivity, shear: Oct 2000
(4) Evaluate the effect of bonding agents to the strength properties of paper in relation to dosage, retention of bonding agents, and fine retention: Oct 2000
(5) Develop methods to specify the location of bond breakage in paper: Dec 2000
(6) Visualize the location of bonding agents in the paper: March 2001
(7) Clarify the way of adsorption for these bonding agents to the fibers under various wet-end conditions using these techniques: June 2001
(8) Visualize the location of bonding agents in paper: June 2001
(9) Evaluate bond quality by determining the location of bond failure: June 2001
(10) Compare the manner of bond breakage due to the bonding agents and dosage levels: June 2001

PROJECT SCHEDULE:

Task Descriptions	2000 July - Sept	2000 Oct - Dec	2001 Jan - Mar	2001 Apr - Jun
Evaluate effect of bonding agents /dosage on strength of paper	----------x			
Visualize bonding agents in paper	----------	----------	----------x	
Characterize bond failure	----------	----------	----------	----------x

DUES-FUNDED PROJECT SUMMARY

Project Title:	**Fundamentals of Accelerated Creep**
Project Number:	**F026**
PAC:	**Paper Physics**
Project Staff:	
Principal Investigators:	**Chuck Habeger, Doug Coffin**
Research Support Staff:	**Barry Hojjatie, Kenisha Collins**
Proposed FY 00-01Budget:	**$108,000**
Allocated as Matching Funds:	**0**
Time Allocation:	
Principal Investigator:	**35%**
Co-Investigators:	**5%**
Research Support Staff:	**38%**
Supporting Research:	
Students:	**Adisak Vorakunpinij (Ph.D.)**
	Chris Dreher (Ph.D.)

RESEARCH LINE/ROADMAP: Line # 11: Improve the ratio of product performance to cost for pulp and paper products 25% by developing:
+ models, algorithms, and functional samples of fibrous structures and coatings which describe and demonstrate improved convertibility and end-use performance
+ breakthrough papermaking and coating processes which can produce the innovative webs with greater uniformity than that achieved by current processes.

- Develop and implement relationships between materials and manufacturing variables AND paper structure, properties, and uniformity
- Develop and implement relationships between paper structure, properties, and uniformity AND end-use performance and convertibility
- Improve papermaking processes
- Improve converting processes

Line #10 – Reduced net energy consumption per ton by 30% compared to '97 levels.

PROJECT OBJECTIVE: Establish that sorption-induced stress gradients and intensification of creep at high load are the root cause of accelerated creep, sorption-induced physical aging, and loss tangent transient phenomena. Determine the influence of mechanical conditioning on the behavior of paper under sustained load. Develop methods to measure residual stresses in paper.

BENEFIT TO THE INDUSTRY, DELIVERABLES: Fundamental understanding of accelerated creep so that rational approaches can be taken to control consequences. Published papers that convincingly argue that our mechanism is the explanation for accelerated creep, sorption-induced physical aging, and loss tangent transients. Assessment of work hardening and second drying as agents for reduction of accelerated creep. Residual stress measurements by x-ray analysis to identify the roles of manufacture and load-moisture history in creep behavior. This understanding,

translated into the ability to decrease basis weight 5% for equal performance in a cyclic humidity environment, would result in a benefit estimated to be about $4MM/yr.

PROJECT STATUS: The experimental and theoretical basis for the sorption-induced stress gradient explanation of accelerated creep and physical aging was established.

GOALS FOR FY 00-01: Fundamental work on accelerated creep will be complete. Work on determining residual stresses will be in progress, and work hardening and second drying study will continue. See schedule below.

(1) Complete loss tangent arguments and fiber accelerated creep experiments: July 2000
(2) Prepare a group of sheets for x-ray analysis: Aug 2000
(3) Do preliminary x-ray studies at ORNL: Sept 2000
(4) Determine the influence of tensile work hardening and second drying on tensile and compressive creep: Mar 2001

SCHEDULE:

Task Descriptions	2000 July - Sept	2000 Oct - Dec	2001 Jan - Mar	2001 Apr - Jun
Complete loss tangent analysis	x			
Measure fiber accelerated creep	---x			
Complete x-ray sheet preparation	------x			
Conduct preliminary x-ray analysis	--------x			
Evaluate x-ray residual stresses	----	----------	----------x	
Complete compression ac work	----------	------x		

DUES-FUNDED PROJECT SUMMARY

Project Title:	**NON-CONTACT LASER ULTRASONIC STIFFNESS MEASUREMENTS**
Project Number:	**F031**
PAC:	**PAPER PHYSICS**
Project Staff:	
Principal Investigators:	**Chuck Habeger**
Co-Investigators:	**John Waterhouse**
Research Support Staff:	**Emmanuel Lafond, Jimmy Jong, Joseph Gerhardstein, Ted Jackson**
Proposed FY 00-01Budget:	**$100,000**
Allocated as Matching Funds:	**100%**
Time Allocation:	
Principal Investigator:	**20%**
Co-Investigators:	**6%**
Research Support Staff:	**51%**
Supporting Research:	
Students:	**none**
External :	**Project 4184 (DOE Agenda 2020)**

RESEARCH LINE/ROADMAP: Line #12 - Reduce pulp and paper product costs by 25% through increased productivity and improved pulp, paper, and product uniformity achieved with developments in sensors and process controls.

PROJECT OBJECTIVE: Design and construct an automated laboratory laser-ultrasonic stiffness instrument. This instrument will be a stand-alone off-line unit that will serve as a reference system for the development of an on-line instrument as supported by the DOE Project 4184.

BENEFIT TO THE INDUSTRY/DELIVERABLES: Areas of potential benefit for an on-line laser-ultrasonic stiffness instrument include more rapid grade changes, less off-spec material, potential energy and raw material savings, and productivity increases. For example, it was estimated that for every 1% increase in overall machine efficiency, increased return of about $0.5MM would be achieved.

Specifically, this project will provide laboratory measurement and on-line monitoring of bending stiffness and out-of-plane shear rigidity. These are real time mechanical properties that will be important for quality and process control. The deliverables are as follows:

1. Associated intellectual property
2. A prototype automated instrument for the non-contact measurement of bending and shear stiffness.
3. Progress Report.

PROJECT BACKGROUND: This is a matching project for a DOE on-line laser ultrasonic contract. The goals are complementary. We plan to use fundamental advances from the DOE work to configure a laboratory tester. Innovations in signal analysis, optical and electronic design, interferometry, and laser technology will be applied in both arenas.

GOALS FOR FY 00-01:

(1) Complete design of automated laboratory laser-ultrasonic stiffness instrument: Sept 2000
(2) Complete building of instrument: Feb. 2001
(3) Evaluate instrument: March 2001

SCHEDULE:

Task Descriptions	2000 July - Sept	2000 Oct - Dec	2001 Jan - Mar	2001 Apr - Jun
Signal analysis to determine elastic props.	----------	----------M		
Instrument design	----------M			
Configure lasers & optics	----------			
Build fiber optics delivery system		----------		
Sample manipulation - robotics	--------	----------M		
Computer control & signal analysis		----------	----------	
Building of Inst.			M	
Evaluation of Inst.		P	-R---------P-----	----------R

P denotes presentation, R denotes either status or progress report, M denotes milestone

DUES-FUNDED PROJECT SUMMARY

Project Title: **Liquid/Substrate Interactions**
Project Number: **F044**
PAC: Fiber and Paper Physics

Project Staff:
Principal Investigator: **Wayne Robbins**
Co-Investigators: **None**
Research Support Staff: **Tabitha Horton**

Proposed FY 00-01Budget: **$86,000**
Allocated as Matching Funds: **0 %**

Time Allocation:
Principal Investigator: **20%**
Co-Investigators: **0%**
Research Support Staff: **60%**

Supporting Research:
Students: None
External: None

RESEARCH LINE/ROADMAP: Line # 11: Improve the ratio of product performance to cost for pulp and paper products 25% by developing:
+ models, algorithms, and functional samples of fibrous structures and coatings which describe and demonstrate improved convertibility and end-use performance
+ breakthrough papermaking and coating processes which can produce the innovative webs with greater uniformity than that achieved by current processes.

- Develop and implement relationships between materials and manufacturing variables AND paper structure, properties, and uniformity
- Develop and implement relationships between paper structure, properties, and uniformity AND end-use performance and convertibility
- Improve papermaking processes
- Improve converting processes

PROJECT OBJECTIVE: The objective of this project is to describe the inter-relationship of surface roughness characteristics, pore size distribution, and the swelling characteristics (surface energy) of cellulose fibers, and how these substrate variables influence the absorption of liquids by dry paper and board. A rigorous model of the relative effects of the substrate properties as a function of applied liquid volume and pressure will be the product. The ultimate goal is that the model be validated and found useful to enable better paper and board manufacturing strategies to control such attributes as print quality (as liquid ink vehicle is absorbed into the substrate), size press effectiveness, and coating/base sheet interactions.

BENEFIT TO THE INDUSTRY/DELIVERABLES: The relevance of understanding the liquid/substrate interactions to process control and product quality is embodied in sizing/body stock, coating/base stock, ink/paper and ink/coating/paper interactions. The knowledge can be applied to both physical phenomena such as crack at fold or dusting,

or appearance issues such as gloss attainment, roughness, and printed surface appearance. It may also provide the basis with which to understand such phenomena as different types of print mottle as it relates to substrate properties.

Deliverables proposed at the fall 1999 PAC that were not formally acted upon include:

1) Methods to establish surface roughness, pore dimensions and surface energy that are traceable and can be used in fundamental mathematical expressions. These methods will span multiple grades. This is not the case with most current methods. Therefore, knowledge gained by Member Companies using these methods in one grade line can be related to other grades produced by that Member Company. The reward of this knowledge is the ability to efficiently gain comparable knowledge across grade lines.
2) Laboratory/pilot methods of liquid application that are relevant to industrial processes. By closing the loop among substrate testing methods and liquid application methods (comparable to industrial processes), Member Companies will be rewarded with the ability to more productively perform product development and relate knowledge gained in one grade line application to other grades.
3) Fundamental mathematical expressions describing the assimilation of liquids over a broad range of applied volume and permitted period of assimilation, and the influence of substrate properties as they affect liquid assimilation. Predictive models improving the efficiency of any product or process development effort will be a reward to the Member Companies.

PROJECT STATUS: This project was proposed at the spring 1999 PAC meeting and accepted as a Dues-Funded project at the subsequent RAC meeting. Goals proposed at that RAC meeting, exploration of theory and methods, were assumed acceptable and were presented at the Fall 1999 PAC meeting. The project was funded beginning July 1999 and was ultimately staffed 30 September 1999.

During the period, a baseline literature search was completed. The intent of this survey was to identify both applicable theory describing liquid/substrate interactions and methods employed in similar efforts. In addition, significant progress was made in identifying and validating traceable methods to characterize surface roughness, surface energy, and pore structure. Finally, laboratory and/or pilot methods of liquid application are being evaluated that approximate those used in a full-scale environment. It is realistic to expect that substrate characterization methods and liquid application techniques will be finalized by the end of FY 99-00.

GOALS FOR FY 00-01:

1) Complete substrate and liquid characterization methodology assessment techniques: July 2000
2) Identify methods to apply liquids to paper and board substrates that are comparable to commercial processes: June 2000
3) Collect roll quantity printing substrate grades representing a range of printing technologies and having a wide range of surface energy, surface roughness, pore structure and fiber composition: Jan 2001
4) Collect a range of liquids/inks representing a wide range of viscosity and surface tension: Jan 2001
5) Perform designed experiments with the substrates and liquids to understand the influence of substrate surface roughness, pore structure and surface energy over a range of applied liquid volume and viscosity: June 2001

6) Perform a set of experiments to establish the effect of pressure of liquid application that is consistent with flexographic, offset and gravure printing applications: Dec 2001
7) Integrate knowledge gained in Goal #'s 6 and 7 into existing theories from Goal #1 to create a predictive model that can be used in process and product development: Dec 2001
8) Test modified theories, as described in Goal # 8, using commercial processes by testing commercially produced products produced during those trials: June 2002

SCHEDULE:

Task Descriptions	2000 July - Sept	2000 Oct - Dec	2001 Jan - Mar	2001 Apr - Jun
1. Design experiment	---------x			
2. Acquire substrate and liquids	---------x			
3. Perform liquid application experiment		--------x		
4. Characterize liquids and paper and board substrates	--------x	---------x		
5. Characterize treated specimens			----------x--------	----------x
6. Interpret data				----------x

Papermaking
Project Advisory Committee

DUES-FUNDED PROJECT SUMMARY

Project Title:	**Fluid Dynamics of Suspensions**
Project Code/Project Number:	**F003**
PAC:	**Papermaking**
Project Staff:	
Faculty/Senior Staff:	**C. Aidun**
Research Support Staff:	**E.J. Ding**
Project Funding:	**$100,000**
Allocated as Matching Funds:	**none**
Time Allocation:	
Principal Investigator:	**10%**
Research Support Staff:	**85%**
Supporting Research:	
Students:	**none**
External:	**none**

RESEARCH LINE/ROADMAP: 11. Improve the ratio of Product Performance to Cost – Models, algorithms, and functional samples of fibrous structures, break-through papermaking processes.

PROJECT OBJECTIVES: Investigate the effect of turbulent flow on individual and collection of fibers in the headbox and the forming section to find the most effective flow field for optimum forming process in various paper grades. Based on the information obtained through the first objective, develop a superior forming process.

BENEFITS TO INDUSTRY/DELIVERABLES: To increase the market share and profitability of the member companies by understanding the physics of fiber suspensions in turbulent flow and optimizing the paper forming and coating processes through break-through technologies in suspension transport to enhance quality and reduce cost.

1. A direct computational method for investigation of individual and collections of fibers in turbulent flow of the headbox and the forming section,

2. Initial computational results and data on fiber orientation and interaction in the converging section of the headbox,

PROJECT STATUS: The initial version of a computational method for analysis of a single fiber suspended in fluid has been completed. This method is based on solution of the discrete Boltzmann equation for the fluid phase and the Newtonian dynamics equations to obtain the fiber translation and rotation. This method currently works for fiber movement in relatively small particle Reynolds Number, Re (based on the magnitude of the shear field and particle size). This method needs to be extended to turbulent flow and much higher particle Re. As it stands, there are limited applications to slow flow processes. Once extended to much higher particle Re, it could be applied to analyze the effect of hydrodynamics on fiber orientation inside the headbox, the forming section, and other paper making processes.

GOALS FOR FY 01:

(1) Complete computational method for analysis of fiber orient in low particle Re regime : Oct. 2000

(2) Extend the current computational method to more applicable flow situations (i.e., turbulent flow in a headbox): Mar. 2001

(3) Examine the impact of headbox hydrodynamics on fiber dispersion and fiber orientation: Ongoing

(4) Issue Annnual Report: June 2001

PROJECT SCHEDULE:

Task Descriptions	2000 Apr - Jun	2000 July - Sept	2000 Oct - Dec	2001 Jan - Mar	2001 Apr-Jun
(1) Extend computational method for analysis of more applicable flow situations	----------	----------	----------	----------x	
(2) Extend application to headbox hydrodynamics				---	----------
(3) Issue annual Report					------x

DUES-FUNDED PROJECT SUMMARY

Project Title:	**Fundamentals of Headbox and Forming Hydrodynamics**
Project Code/Project Number:	**FORM / F005**
PAC:	**Papermaking**
Project Staff:	
Faculty/Senior Staff:	**C. Aidun**
Research Support Staff:	**McKay, Bandhakavi, Hooda**
Project Funding:	**$239,000**
Allocated as Matching Funds:	**none**
Time Allocation:	
Principal Investigator:	**20%**
Research Support Staff:	**220%**
Supporting Research:	
Students:	**none**
External:	**none**

RESEARCH LINE/ROADMAP: Paper Machine Productivity and Quality; cost effectiveness

PROJECT OBJECTIVES:

I. Investigate the fluid flow interaction with fiber network in a headbox and the forming section; improve designs for reduction of floc formation and improvement of fiber dispersion in headbox and the forming section;

II. Develop methods for measurement of the velocity profile in CD and MD of the forming jet and influence on physical properties. Use this method as a diagnostics tool for process optimization to improve formation and reduce consumption of raw material.

BENEFITS TO INDUSTRY/DELIVERABLES: To increase the market share and profitability of the member companies by Optimization of the Headbox and the Forming Section to enhance quality and reduce cost.

DELIVERABLES by June 00:

1. The velocity profile for the free-surface forming jet using the SPIV method;
2. An on-line method for measurement of the CD velocity profile on the surface of the forming jet as a diagnostics tool for process optimization

DELIVERABLES FOR FY 00-01:

1. Results from visualization of floc formation and breakup at various sections of the headbox as a mean to understand and optimize process parameters for best formation

2. An on-line method for measurement of the velocity profile along the thickness of the forming jet from the slice to the impingement zone as a diagnostics tool for process optimization.

3. Relation between the mean and averaged velocity profile and streaks in the forming jet with the physical properties such as fiber orientation and dimensional instability
4. The relation between velocity profile and the design features of the headbox
5. Practical methods to optimize process parameters in order to minimize velocity profile nonuniformity, with the goal of improving uniformity of physical properties

PROJECT STATUS: The two-component laser-Doppler velocity (LDV) measurements of the streamwise velocity and azimuthal component of the mean and turbulent fluctuations through the step expansion tube provide details of the flow characteristics in a headbox tube. With this information, and visualization of the floc breakup and dispersion mechanism, and the effectiveness of the headbox design can be examined. The floc dispersion mechanism at the step expansion section of the headbox tube has been examined. Methods to quantify the floc breakup and fiber dispersion as a function of flow rate and the dimension of the step change have been developed. The results show strong correlation between the mean axial velocity gradient through the transition from small diameter to larger diameter tube and the floc breakup and fiber dispersion. The fiber dispersion seems to be based on the turbulent eddy formation where the floc deformation, rupture and breakup are from the extensional flow and radial stresses.

An automated SPIV system is constructed with the necessary software to use for on-line optimization of process parameters in the forming section. The SPIV method has been applied to a commercial system and results are used for optimization of the process parameters to improve the fiber orientation profile.

GOALS FOR FY 01:

(1) Complete mechanism for floc formation and breakup in the headbox:: Oct. 2000

(2) Develop a method for measurement of the velocity profile along the thickness of the forming jet: Mar 2001

(3) Identify the headbox design features that lead to velocity profile nonunifomity: June 2001

(4) Develop practical methods to optimize process parameters in order to minimize velocity profile nonuniformity, with the goal of improving uniformity of physical properties: June 2001

(5) Issue Annual Report: June 2001

PROJECT SCHEDULE:

Task Descriptions	2000 Apr - Jun	2000 July - Sept	2000 Oct - Dec	2001 Jan - Mar	2001 Apr-Jun
(1) Evaluate floc dispersion/ formation	----------	----------	-----x		
(2) Develop on-line velocity measurement system					
2.1 Exp. setup	----	---x			
2.2 Experiments		---------	-----x		
2.3 data analysis			----------	---x	
2.4 interim report				---x	
(3) Analyze mean velocity and surface patterns				----------x	
(4) Measure velocity profile				----------x	
(5) Minimize velocity nonuniformity	----------	----------x			-----x
(6) Issue Annual Report					------x

DUES-FUNDED PROJECT SUMMARY

Project Title:	**Drying Productivity**
Project Number:	**F021**
PAC:	**Papermaking**
Project Staff:	
Principal Investigators:	**F. Ahrens, T. Patterson**
Research Support Staff:	**Mueller, Phelan, Rudman, Abazeri, Lindahl**
Proposed FY 00-01Budget:	**$150,000**
Allocated as Matching Funds:	**74%**
Time Allocation:	
Principal Investigator:	**15%**
Research Support Staff:	**135%**
Supporting Research:	
Students:	**none**
External (Where Matching Is Used):	**Project 4253 (DOE-$400,000)**

RESEARCH LINE/ROADMAP: Line 7 - Increase paper machine productivity by 30% over '97 levels via focus on breakthrough forming, dewatering, and drying concepts (faster drying and improved runnability/quality).

PROJECT OBJECTIVE: Understand and reduce the impediments (e.g., picking/sticking, surface deposits, cockle, sheet sealing) to the use of higher surface temperatures in the first dryer section. Provide fundamental knowledge and tools needed to design new technologies that will allow ultra high speed web transfer.

BENEFIT TO THE INDUSTRY/DELIVERABLES: Success in developing strategies for operating at higher surface temperatures in the first dryer section, while reducing picking/sticking, surface deposits, cockle, etc., will result in significant productivity improvement via both increased drying capacity and increased yield of good product. It was projected that a 5% productivity increase on a dryer-limited machine would result in about a $3MM/yr improvement in mill profitability.

Two deliverables are available or will be available in the near term:

- WADS, for measurement of adhesion/picking of member-specific furnishes and conditions. (03/00)
- A comprehensive methodology, (with appropriate documentation) for collection and analysis of roll topology and contamination samples and estimation of contamination effects on dryer efficiency. (05/00)

PROJECT STATUS:

- Dryer surface topology and contamination samples for three grades (four paper machines) have been collected/analyzed.
- The Web Adhesion and Drying Simulator (WADS) is in use to investigate effect of operating variables on picking and adhesion for clean and contaminated dryer surfaces

- Contamination Test Stand (CTS) is in use for investigating the development of contamination on roll surfaces.
- An initial investigation of the effect of drying variables on cockle (in collaboration with Project F020) was completed. Results indicate that non-uniform contamination has a demonstrated impact on cockle development.

GOALS FOR FY 00-01:

(1) Complete documentation on comprehensive methodology, for collection and analysis of roll topology and contamination samples: May 2000
(2) Develop empirical data/models for contamination, picking/adhesion: Oct 2000
(3) Develop empirical data/models for cockle: Oct 2000
(4) Develop web transfer model: Mar 2001
(5) Evaluate drying strategies and develop dryer section operating strategies and guidelines (for reduced picking, cockle, surface deposits and improved productivity): Mar 2001
(6) Evaluate/develop surface conditioning technologies: June 2001

SCHEDULE:

Task Description	2000 Apr-June	2000 July – Sept	2000 Oct – Dec	2000 Jan – Mar	2000 Apr - Jun
Collect dryer contamination/ topology infor.	x	-----X			
Develop experimental equipmt: WADS, CTS	x				
Web adhesion/picking experiments	-----X	-----X	-----X		
Cockle experiments	-----X	-----X			
Develop web transfer model		-----X	-----X	-----X	
Develop/evaluate improved drying strategies	-----X	-----X	-----X	----------X	
Develop/evaluate surface conditioning technologies		-----X	-----X	-----X	----------X

DUES-FUNDED PROJECT SUMMARY

Project Title: FLOW THRU POROUS MEDIA
Project Number: F022
PAC: PAPERMAKING

Project Staff:
Principal Investigator: Seppo Karrila
Co-Investigators: Ted Jackson

FY 00-01 Budget: $104,000
Allocated as Matching Funds: 0%

Time Allocation:
Principal Investigator: 40%
Co-Investigators: 33%

Supporting Research:
M. S. Students: Andres Navia

RESEARCH LINE/ROADMAP: Line #11 - Improve ratio of product performance to cost for pulp and paper products by 25% by developing breakthrough papermaking and coating processes that can produce innovative webs with greater uniformity than achieved by current processes.

PROJECT OBJECTIVE: Improve control of the layered structure of a paper web in its thickness direction. Clarify the mechanisms affecting formation and retention on the wire section and use these to decouple formation and retention. Provide proof-of-concept in laboratory scale of either next generation forming elements or breakthrough forming methods that help accomplish this.

BENEFIT TO THE INDUSTRY/DELIVERABLES: Benefits include (1) better engineering of the layered structure of the product, increasing product value vs. the cost of raw materials (typical application: fiber replacement with mineral filler), (2) improved balance among retention, formation, and drainage speed, which is necessary as production speeds are increased, and (3) increasing high-vacuum dewatering efficiency, translated into improved runnability, higher machine speed, or energy savings. Projected rewards: (1) decrease in breaks from 3% to 2% is worth about $850K/yr (IPST Econ. Model); (2) increased filler content of 5% absolute: about $ 600 K/yr; (3) chemical cost savings of 15% or $2/ton = $700 K/yr. Even more significant, breakthrough rewards are possible with new forming concepts

Deliverables will include (1) improved diagnostic laboratory methods for analyzing the structure of paper samples; (2) laboratory procedures for maximizing the solids content off couch and tuning the stock composition; (3) laboratory procedures that help maximize the filler content, with constraints on process runnability and product quality; (4) evaluation of the opportunity to decouple formation and retention, based on quantified mechanisms; and (5) based on the evaluation in (4), demonstration of improvements of forming elements or breakthrough forming method(s) on the laboratory scale.

PROJECT STATUS: The construction of the MBDT (Moving Belt Drainage Tester) device is underway. Initial testing and debugging will start in June/July 2000. The drawings have been reviewed in detail, improved where necessary, and organized into several subassemblies so that machining work can be subcontracted to external machine shops as separate sub-projects.

Phenomena and models for particle migration in porous media have been reviewed to enhance understanding of the mechanisms determining retention and its layerwise profile in the paper web. The key element absent from earlier papermaking models for flow through formed web layers is the detachment of migrating particles. This appears to be the phenomenon responsible for filler depletion at the water exit surface of a formed web, possibly in combination with layerwise compression during a suction pulse. The phenomenological models collected will be used in numerical simulations, in connection with pulsating drainage experiments. The pulse rate of the MBDT is known to affect the z-distribution of filler strongly.

GOALS FOR FY 01:

(1) As first application of MBDT, pursue increasing filler content of alkaline fine paper; in the initial stage, identify a target machine to pattern the conditions after, and collect pulp from mill, study the effects of primary MBDT variables on forming performance: Oct 2000
(2) Begin development of numerical model for particle migration: Oct 2000
(3) Develop an industry approach to forming in collaboration with Dr. Aidun (the approach will be reviewed, improved, and pursued after the meeting): Oct 2000
(4) Based on initial results, select and pursue approach to increasing filler loading; e.g., find maximum filler loading achievable under optimal conditions based on product quality or other constraints ("optimal conditions" are for lab forming, showing the limit of what could be achieved in production scale): June 2001
(5) Pursue industry approach to forming as agreed in Fall 2000 PAC: June 2001

PROJECT SCHEDULE:

Task Descriptions	2000 Apr - Jun	2000 July - Sept	2000 Oct - Dec	2001 Jan - Mar	2001 Apr-Jun
1. Complete lit. survey of alkaline fine paper	---------x				
2. Build MBDT equipment	------	-x			
3. Complete initial testing		---x			
4. Run filler loading experiments		------x	-------	----------	----x
5. Issue fall PAC report		--- ---	--x		
6. Develop model	-		----------	-----	----x
7. Write yearly report					-----x
8. Develop & pursue "industry approach to forming"	---	---	----	--------	------x

DUES-FUNDED PROJECT SUMMARY

Project Title:	**Overcoming the Fundamental Water Removal Limitations of Conventional Wet Pressing**
Project Number:	**F039**
PAC:	**Papermaking**
Project Staff:	
Principal Investigator:	**T. Patterson**
Research Support Staff:	**. Rudman, D. Edelkind**
FY 99-00 Budget:	**$96,000**
Allocated as Matching Funds:	**0%**
Time Allocation:	
Principal Investigator:	**17%**
Research Support Staff:	**107%**
Supporting Research:	
Special Students:	**Robert Jeyaseelan**

RESEARCH LINE/ROADMAP: Line #7 - Increase paper machine productivity by 30% over 1997 levels via focus on breakthrough forming, dewatering, and drying concepts.

PROJECT OBJECTIVE: Develop through theoretical, experimental and pilot scale studies a non-drying, dewatering technology that will produce sheet solids levels that equal the theoretical maximum for non-drying methods.

BENEFIT TO THE INDUSTRY/DELIVERABLES: Conventional pressing is not capable of producing sheet solids levels that approach the theoretical maximum for non-drying methods; sheet and fiber compressibility limit the maximum sheet solids. This project is aimed at attaining solids levels that approach the theoretical maximum for non-drying methods, requiring the use of alternative "driving forces" that are not the result of the application of mechanical pressure. It has been estimated that a new wet pressing process delivering a ten percentage point increase in exiting sheet solids, resulting in a 25% increase in production on a dryer-limited machine, would result in increased profitability (not including the cost of capital) of about $14MM/yr. Deliverables include:

- Literature review directed at understanding the current limitations on wet pressing and possible methods for overcoming those limitations. Completed literature search will be submitted as an IPST Member Report (Oct 00).
- Laboratory scale experimental apparatus for implementing displacement dewatering (Oct 00).
- Documentation of technical and economic feasibility of displacement dewatering, based on experimental work, providing a go/no go decision point for the project (Mar 01).

PROJECT STATUS:

- A literature review directed at understanding the current limitations on wet pressing and possible methods for overcoming those limitations was initiated.
  - Conventional pressing is not capable of producing sheet solids levels that approach the theoretical maximum for non-drying methods. Sheet and fiber compressibility limit the maximum sheet solids.
  - Attaining solids levels that approach the theoretical maximum for non-drying methods will require the use of alternative "driving forces" that are not the result of the application of mechanical pressure, e.g., conventional pressing.
- A review of the literature, previous IPST research, and the potential mechanisms for sheet dewatering yielded several possibilities:
  - Fiber modification.
  - Ultrasound application during pressing.
  - A modified form of displacement dewatering.
- Given the fundamental mechanisms operating, displacement dewatering has the greatest potential.

GOALS FOR FY 01

(1) Write a review of published pressing, fiber physics, and sheet chemistry literature based on literature reviewed for March 00 meeting: Oct 2000
(2) Assemble/modify experimental equipment to allow displacement dewatering and sheet compression measurements: Oct 2000
(3) Investigate potential collaboration with press section manufacturer: Oct 2000
(4) Implement "optimized" displacement dewatering at the laboratory scale and evaluate its potential: March 2001
(5) Estimate capital cost of a commercial installation: March 2001

PROJECT SCHEDULE:

Task Descriptions	2000 Apr - June	2000 July - Sept	2000 Oct - Dec	2001 Jan - Mar	2001 Apr - June
1. Survey literature	x				
2. Write up lit Survey	----	----------	--x		
4. Review F001 & F002 Research	x				
5. Prioritize potential methods	x				
6. Set up experiment equipment	-----	----------x			
7. Perform experiments		----	----------x		
8. Evaluate experiments				---------x	

DUES-FUNDED PROJECT SUMMARY

Project Title:	**Extending High Intensity Water Removal Principles into the Dryer Section**
Project Number:	**F041**
PAC:	**PAPERMAKING**
Project Staff:	
Principal Investigator:	**F. Ahrens**
Co-Investigators:	**P. Phelan, I. Rudman**
Research Support Staff:	**Lindahl, Abazeri**
Proposed FY 00-01Budget:	**$84,000**
Allocated as Matching Funds:	**0%**
Time Allocation:	
Principal Investigator:	**10%**
Co-Investigators:	**33%**
Research Support Staff:	**49%**
Supporting Research:	
Students:	**N. Alaimo, M.S.**
External:	**None**

RESEARCH LINE/ROADMAP: Line #7 - Increase paper machine productivity by 30% over 1997 levels via focus on breakthrough forming, dewatering, and drying concepts [faster drying]

PROJECT OBJECTIVE: Demonstrate/verify a high intensity drying concept that provides the basis for a feasible, high productivity, capital/space/energy effective dryer system. Provide the data and understanding needed for development.

BENEFIT TO THE INDUSTRY/DELIVERABLES: For retrofit of existing machines, it will be possible to install significant extra capacity in a small space and at a lower capital cost than for comparable conventional capacity. For new machines, greatly reduced space and capital cost, and increased efficiency will be achieved, and the very low drying rates and enormous dryer sections of today will be eliminated (1 - 6 high intensity dryers *vs.* 40 –120 conventional dryer cylinders). Product uniformity will be improved through greater restraint of the sheet and better control over the surface properties of the sheet. It was estimated that a new process delivering a 25% increase in production on a dryer-limited machine would result in increased profitability (not including the cost of capital) of about $14MM/yr.

DELIVERABLES for FY 00-01 include (1) a computer model of the Paprican impingement dryer concept (Sept 2000), (2) results of preliminary technical/economic evaluation (Dec. 2000), (3) a proposal for pilot/moving web demonstration/evaluation (Dec. 2000), and (4) a commercialization plan (Mar. 2001).

PROJECT STATUS: A preliminary high-intensity dryer concept is in place. Initial laboratory experiments in support of concept development and demonstration of high drying rate potential have been completed. A plan for further concept refinement (including addressing of clothing/equipment issues) is being developed. A new task (interaction with Paprican to model their impingement dryer concept) has been proposed for initiation in Spring 2000.

GOALS FOR FY 00-01:

(1) Complete a preliminary technical and economic assessment (including clothing and equipment issues): Sept 2000
(2) Complete the model of Paprican impingement dryer concept: Sept 2000
(3) Develop a commercialization plan for high-intensity dryer: Dec 2000
(4) Develop a proposal for pilot demonstration/evaluation: Dec 2000
(5) Refine the high-intensity dryer concept: Mazr2001

MILESTONES (FY 00-01):

- Results of preliminary technical/economic evaluation support continuation: Sept 2000
- Decision to proceed into pilot/moving web phase: Dec 2000

SCHEDULE:

Task Description	2000 Apr - June	2000 July - Sept	2000 Oct - Dec	2001 Jan - Mar	2001 Apr- June
Develop promising concept	X				
Concept refinement		X	X	X	
Identify equipment/clothing issues	X	X			
Preliminary technical/economic evaluation	X	X			
Develop commercialization plan	X	X	X		
Develop model of PAPRICAN concept	X	X			
Develop proposal for pilot demonstration/ evaluation		X	X		
Obtain data for scale-up (moving web system)				X	X

DUES-FUNDED PROJECT SUMMARY

Project Title:	**Approach Flow Systems**
Project Number:	**F048**
PAC:	**Papermaking PAC**
Project Staff:	
Principal Investigator:	**D. E. White**
Research Support Staff:	**A. Giorges, A.Garner**
Proposed FY 00-01Budget:	**$115,000**
Time Allocation:	
Principal Investigator:	**10%**
Research Support Staff:	**101%**

RESEARCH LINE/ROADMAP: Line #11: Improve the ratio of product performance to cost for pulp and paper products by 25% by developing break-through papermaking and coating processes that can produce the innovative webs with greater uniformity than that achieved with current processes.

PROJECT OBJECTIVE: The objective of this project is to improve the spatial and temporal consistency and chemical uniformity of the stock leaving the approach flow area, leading to improved MD uniformity. This will be accomplished using a mill-validated fiber mixing model that can be applied to mill approach systems.

BENEFIT TO THE INDUSTRY/DELIVERABLES: This project will provide selected approach flow guidelines to paper producers. A model of the fiber mixing process will also be developed for the industry. This will provide a tool to pulp and paper producers that will allow them to design approach flow configurations (and other piping systems) to optimize mixing performance given economic and space limitations. The project will deliver the ability to model approach flow scenarios for rebuilds on a contract basis. Improvement in the approach flow design is expected to lead to increased sheet uniformity. It was estimated that for every 1% increase in overall machine efficiency, increased return of about $0.5MM would be achieved.

PROJECT STATUS: Since July 1999, a concentric mixing experimental facility has been modified to obtain water-water mixing observations at velocity ratios as high as 6:1. A model of the mixing process was applied to a water-water concentric mixer, and good qualitative agreement between the experiments and predictions was realized. A model of the fiber mixing process was also proposed.

GOALS FOR FY 01:

(1) Issue Member Company report on water-water mixing studies: Sept 2000
(2) Complete experimental concentric mixing studies and computations for water – ~1% hardwood fiber suspensions: Sept 2000
(3) Identify, with the help of the Papermaking PAC, a machine with a non-optimal approach flow system where data can be collected and where future changes can be assessed for extent of success: Nov 2000
(4) Calculate reward obtainable with improved approach flow design: Nov 2000
(5) Complete experimental concentric mixing studies and computations for water – 3-4% hardwood fiber suspensions: Mar 2001

(6) Complete experimental concentric mixing studies and computations for water – softwood fiber suspensions: June 2001
(7) Continue numerical parametric studies of the concentric mixing process: June 2001
(8) Write Member Reports on model validation work and on numerical parametric studies: June 2001

PROJECT SCHEDULE:

Task Description	2000 Apr - Jun	2000 July -Sept	2000 Oct - Dec	2001 Jan - Mar	2001 Apr - Jun
1. Run ~1% HW exps	----------x				
2. Issue Member Co. report on water-water mixing	----------	----------x			
3. Complete analysis of 1% HW runs		----------x			
4. Complete simulation of 1% HW runs	----------	----------x			
5. Identify mill			---------x		
6. Calculate rewards		--	---------x		
7. Complete 3-4% HW exps, analyses, and simulations		--	----------	----------x	
8. Run 1% SW exps					----------x
9. Continue parametric studies of concentric mixing	----------	----------	----------	----------	----------
10. Draft Member Co. Reports on modeling work and on parametric studies on HW					---------x

Recycle
Project Advisory Committee

DUES-FUNDED PROJECT SUMMARY

Project Title:	**FLOTATION DEINKING FLUID MECHANICS**
Project Number:	**F00903**
PAC:	**Recycle**
Project Staff:	
Principal Investigator:	**S. Shrauti**
Research Support Staff:	**A. Garner, F. Bloom (consultant)**
Proposed FY 00-01Budget:	**$112,000**
Time Allocation:	
Principal Investigator:	**30%**
Research Support Staff:	**45%**

RESEARCH LINE/ROADMAP: Line 13: Reduce and/or control contaminants (e.g., stickies, dyes, toners) in recycle fiber pulp using break-through technologies to allow the interchange of recycled pulp with virgin pulp of similar fiber makeup at an economical cost.

PROJECT OBJECTIVE: The objective of this project is to increase flotation efficiency by maximizing contaminant removal from waste paper while minimizing fiber loss.

BENEFIT TO THE INDUSTRY/DELIVERABLES: A flotation deinking model will allow paper recyclers to (i) predict effects of process changes before expensive system trials are implemented, (ii) predict changes to improve current flotation cell operation, and (iii) predict performance of new flotation cell design. Methods to control bubble size in flotation deinking cells will improve removal efficiency, and they can be applied to other areas in a mill where gases are introduced into a fiber suspension. Based on a 1000 tpd recycle plant, reward would be (1) a one-time capital savings of $800,000 is projected due to improved flotation efficiency, where the scenario is retrofitting one flotation cell (cost: $800,000), and (2) overall savings of $5/ton due to yield increase ($1/ton, or $400,000), chemical savings, and use of lower grade furnish.

PROJECT BACKGROUND: This project has focused on two parallel research paths. One investigating the development of a flotation deinking model. The other pursuing bubble size measurement and control strategies in a fiber suspension. These two paths are leading us to improve the flotation deinking performance. The PAC has requested that the flotation deinking model validation work should be the focus of FY01, and the bubble size control strategies should be delayed until at least FY02.

GOALS and MILESTONES FOR FY 01:

(1) Improve P_{asl} in the flotation model: Oct 2000
(2) Aply the flotation model to a continuous process: Oct 2000
(3) Identify required methods and techniques needed to measure the necessary parameters in a pilot or mill setting for model validation of the toner deinking process: Oct 2000
(4) mprove P_{stab} in the flotation model: Dec 2000
(5) Identify actual pilot or mill facility for trials: Dec 2000
(6) Validate model with actual pilot (mill) data: May 2001
(7) Issue Member Company Report summarizing flotation modeling: June 2001

PROJECT SCHEDULE:

Task Description	2000 Apr - Jun	2000 July -Sept	2000 Oct - Dec	2001 Jan - Mar	2001 Apr - Jun
1. Improve P_{asl}	----------	----------	----x		
2. Continuous model	------	----------	----x		
3. Experimental method and technique identification		----------	-----x		
4. Improve P_{stab}		----------	----------x		
5. Identify pilot/mill facility for validation trials		--------	----------x		
6. Run trial to validate model				----------	------x
7. Issue report					----------x

DUES-FUNDED PROJECT SUMMARY

Project Title: **On-line Real Time Quantification of Stickie Contaminants**

Project Number: **F042**

PAC: **Recycle**

Project Staff:

Principal Investigator: **S. Banerjee**

Co-Investigators: **S. Shrauti**

FY 00-01 Budget: **$87,000**

Time Allocation:

Principal Investigator: **15%**

Co-Investigators: **30%**

Supporting Research:

Students: **Greg Fike (Ph.D.)**

RESEARCH LINE/ROADMAP: Line 13. Reduce and/or control contaminants (e.g., stickies, dyes, toners) in recycled fiber pulp using breakthrough technologies to allow the interchange of recycled pulp with virgin pulp of similar fiber makeup at an economical cost.

PROJECT OBJECTIVE: Develop and field test on-line stickies sensor capable of quantifying both macro- and micro stickies in recycle mill pulp streams.

BENEFIT TO THE INDUSTRY/DELIVERABLES: The stickies sensor will allow chemical costs to be reduced by allowing the amount of chemicals to be matched to the level of stickies present. Also, downtime will decrease, product quality and yield will improve, and there will be an opportunity to use a lower grade recycle furnish. Savings of at least $1.5 MM per year would be achieved for a 1000 tpd recycle plant based on a $5/ton reward .

PROJECT STATUS: The objective of the project is to develop an on-line sensor for quantifying stickies. Macrostickie work has been completed, and work is proceeding on a microstickies sensot.

GOALS FOR FY 01:

(1) Test the elements of the microstickie sensor: Oct. 00
(2) Build and lab-test a complete device: Mar. 01
(3) Initiate mill trial: June 01

PROJECT SCHEDULE:

Task Description	2000 Apr - Jun	2000 July -Sept	2000 Oct - Dec	2001 Jan - Mar	2001 Apr - Jun
1. Test sensor	----------	----------	--x		
2. Build, lab-test device			----------	---------x	
3. Initiate mill trial					---------x

DUES-FUNDED PROJECT SUMMARY

Project Title: **Reversal of Fiber Hornification**
Project Number: **F054**
PAC: **Recycle**

Project Staff
Principal Investigator: **S. Banerjee**
Co-Investigators: **S. Shrauti**

FY 00-01 Budget: **$30,000**
Allocated as Matching Funds: **0%**

Time Allocation:
Principal Investigator: **5%**
Co-Investigators: **29%**

RESEARCH LINE/ROADMAP: Reduce and/or control contaminants in recycled-fiber pulp using breakthrough technologies to allow complete interchange of recycled pulp with virgin pulp of similar fiber make-up at economical cost.

PROJECT OBJECTIVE: The objective of this exploratory study is to determine whether it is possible to dehornify secondary fiber. The work is based on a recent finding that dielectric heating enhances the diffusion rate of liquids in solids. The study will determine whether dielectric heating can move water into occluded regions of dried fiber and, thereby, enhance hydrogen bonding.

BENEFIT TO THE INDUSTRY/DELIVERABLES: The benefit to the industry would be increased strength of packaging materials and/or the ability to use more recycled fiber. The differential between virgin and recycle fiber varies but can be on the order of $25-50 per ton of fiber.

PROJECT STATUS: New project

GOALS FOR FY 01:
(1) Plan experimental design, methods (Aug. 00)
(2) Run preliminary experiments (Sept. 00)
(3) Complete experimental program (Mar. 01)
(4) Develop Model (Mar. 01)
(5) Evaluate Economics (May 01)
(6) Write yearly report on project feasibility, recommending future action (June 01)

PROJECT SCHEDULE:

Task Description	2000 Apr - Jun	2000 July -Sept	2000 Oct - Dec	2001 Jan - Mar	2001 Apr - Jun
1. Plan experiments	----------	--x			
2. Develop methods	----------	----------x			
3. Run experiments		---x	----------	---------x	
4. Develop model				---x	
5. Interpret data					--x
6. Evaluate economics					---x
7. Recommend future action (report)					-----x

Wet End Chemistry
Project Advisory Committee

DUES-FUNDED PROJECT SUMMARY

Project Title:	**Wet End Chemistry Control Advisor (WECCA)**
Project Number:	**F027**
PAC:	**Wet End Chemistry**
Project Staff:	
Principal Investigator:	**Bill Scott (20%) (Miami U. and Adjunct IPST)**
Co-Investigators:	**none**
Research Support Staff:	**none**
PAC Subcommittee	**None**
FY 00-01 Budget:	**$50,000**
Allocated as Matching Funds:	**0%**
Time Allocation:	
Principal Investigator:	**20%**
Co-Investigators:	**0%**
Research Support Staff:	**0%**
Supporting Research:	
Special Students:	**none**
External (Where Matching Is Used):	**none**

RESEARCH LINE/ROADMAP: No. 12: Reduce pulp and paper costs by 25% through increased productivity and improved pulp, paper, and product uniformity achieved with new developments in sensors and process controls.

PROJECT OBJECTIVES: Develop and implement an advanced first pass retention control strategy that predicts mill retention upsets and guides the operator to the appropriate, preemptive response. For FY 00-01, install first pass retention model in the West Carrolton Mill, in a supervisory mode and evaluate its effectiveness in reducing retention variability and improving operator control of the paper machine. Prepare a final report.

BENEFITS TO INDUSTRY/DELIVERABLES: The industry needs advanced process control strategies that will simultaneously deal with the multiple, interacting variables involved in wet end chemistry. Implementation of such strategies will improve the efficiency of chemical additive use and enhance product quality and machine productivity. The specific benefits to be gained from the initial phase of this project include improved ability to avoid process and upsets associated with variable fines retention, a cleaner wet end system, and more uniform product quality in those grades where fines retention is important. It was estimated that a reduction in breaks from 3 to 2.5% is work about $400,000/yr, and that a 5% absolute increase in filler content is woth about $600,000/yr.

1. Deliverable 1: A paper machine computer simulation, based on the Simons Technologies IDEAS program, that will enable an operator to predict the tray consistency on a paper machine as a function of current conditions throughout the

stock preparation and paper machine system by May 1, 2001. Potential paybacks will be paper machine-specific, but could be significant due to the relatively low implementation costs involved.
2. Deliverable 2: A set of procedures to follow when implementing Deliverable 1 in a given mill and for a given machine.

PROJECT STATUS: A comprehensive set of process data has been collected from the No. 93 paper machine at the Appleton Papers West Carrolton, OH mill. The data set was found to be unsuitable for the development of an empirical retention control model. Instead, it was used in the development of a mass balance-based simulation of the paper machine. In addition, fines and cationic demand surveys were carried out around the thick and thin stock areas of the machine. The bookstock input stream was found to be the most significant source of cationic demand and fines.

A dynamic mass balance simulation of No. 93 paper machine was developed using the *IDEAS* software package provided by Simons Technologies. The modeling process was found to be only moderately difficult and could be done by any experienced process engineer having up-to-date P&ID diagrams. The simulation will serve as the foundation for wet end chemistry modeling, which is the next stage in the project. As it currently exists, the simulation could be used to investigate white water closure strategies and contaminant buildup in the paper machine system.

SUMMARY OF KEY CONCLUSIONS:

- The Internet provides a convenient way to acquire mill process data for use in off-site projects.
- No. 93 paper machine exhibits relatively stable, steady state operation over very long time periods.
- The process data collected from No. 93 paper machine are unsuitable for the development of an empirical model.
- The bookstock stream provides most of the cationic demand introduced into the paper machine system. It also introduces the majority of the fines.
- On-line charge measurement is needed on at least the bookstock stream.
- A dynamic mass balance model could be developed from mill P&ID diagrams and the process data described above. The model will serve as the foundation for a wet end chemistry control model.

GOALS FOR FY 01:

1. Complete the creation of a model for No. 93 paper machine using the Kodiak simulation program. The model should be able to predict tray consistency as a function of time under varying machine conditions: Oct 2000
2. Test the model against a data set derived from historic mill data: Oct 2000
3. Install the model on No. 93 paper machine and evaluate its effectiveness as a retention process control aid: June 2001
4. Prepare a final project report: June 2001

PROJECT SCHEDULE:

Phase	2000 Apr - Jun	2000 July - Sept	2000 Oct - Dec	2001 Jan - Mar	2000 Apr-Jun
Complete model creation with Kodiak and mill data	----------	------X			
Implement model in mill		------	------X		
Evaluate model in mill			------	----------	------X
Issue final report and recommendations					------X

DUES-FUNDED PROJECT SUMMARY

Project Title:	**Wet End Chemistry Understanding and Control**
Project Number:	**F043**
PAC:	**Wet End Chemistry**
Project Staff	
Principal Investigator:	**Y. Deng**
Research Support Staff:	**Y. Xu**
FY 00-01Budget:	**$88,000**
Allocated as Matching Funds:	**None**
Time Allocation:	
Principal Investigator:	**25%**
Research Support Staff:	**57%**
Supporting Research:	
Students:	**Paivi Hanvy (M.S.)**

RESEARCH LINE/ROADMAP: Line 12 - Reduce pulp and paper product costs by 25% through increased productivity and improved pulp, paper, and product uniformity achieved with new developments in sensors and process controls.

PROJECT OBJECTIVE: Develop a comprehensive understanding of:

- anionic trash,
- interaction kinetics and selectivity among cationic polymers, anionic trash, and solid suspensions
- adsorption of anionic trash on the surfaces of fillers, fines and fibers

These studies will lead to recommendations for the most suitable charge measurement method, for cationic fixation agents, and for improved retention agents.

BENEFIT TO THE INDUSTRY/DELIVERABLES: Information about charge neutralization between cationic polymer and anionic trash will give a guideline for our member companies to control wet-end chemistry, particularly for white water closure systems. By developing a fundamental understanding of the wet-end chemistry in closed white water, Member Companies will be able to significantly reduce chemical cost and improve product quality. This project will recommend: 1) the most effective cationic fixation agent for neutralization of anionic trash (reduce chemical use by 15%, saving $850K/year (IPST model); 2) the correct use of available methods for measuring the charge characteristics in pulp furnish (reduction of 2-3% of breaks will save $850K/year; increase filler loading by 5% will save $600K/year); 3) the method for correct use of retention aid (increase in filler loading of 5% and reduction in chemical use will save 600K/year). Results will also allow improvement in paper-machine runnability by reducing contaminant deposition and will reduce environmental impact.

PROJECT STATUS: Results indicated that the cationic demand does not equal to the polyDADMAC demand. Cationic demand strongly depends on the polymer structure.

Colloidal titration using a streaming current detector is strongly case dependant, i.e. a small change in the environment will cause a significant change in the titration results.

GOALS FOR FY 01:

(1) Compare colloidal titration methods (streaming current detector vs. color detector) and recommend better one for charge measurement: Oct. 2000

(2) Compare commercially available and new charge measurement methods and recommend the best one: Mar. 2001

(3) Investigate the fixation of anionic trash on fiber, fines, and fillers by cationic polymers: June 2001

PROJECT SCHEDULE:

Task Description	2000 Apr - Jun	2000 July -Sept	2000 Oct - Dec	2001 Jan - Mar	2001 Apr - Jun
1. Compare colloidal titration methods (streaming current detector vs. color detector) and recommend better one for charge measurement	----------	----------	----x		
2. Develop a new membrane separation method for studying charge neutralization/ measurement			----------	----------x	
3. Evaluate relationship between chemical structure and colloidal particle formation (charge neutralization)				----------	----------x